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A Productivity Study of Canadian Air Carriers,
Research Report No. 1984/04E

The small Table on page xii and Table 3.2 on page 23 should read as follow:

- xii -

ANNUAL PERCENTAGE RATES OF GROWTH OF FACTOR PRODUCTIVITIES

Period	Air Canada	CP Air	PWA	Nordair	Quebecair	EPA
1960-1976	3.4	5.6	1.7	-0.3	2.1	1.1
1977-1981	0.3	1.7	-0.2	2.8	2.4	-1.8
1960-1981	2.9	4.8	1.6	0.6	2.4	0.8

- 23 -

Table 3.2

ANNUAL PERCENTAGE RATES OF GROWTH OF FACTOR PRODUCTIVITY
Regional Carriers

	PWA		Nordair	
Period	CRO/TFI 1	CRO/TFI 2	CRO/TFI 1	CRO/TFI 2
1960-1976	4.1	1.7	0.8	-0.3
1960-1968	2.5	-0.8	-0.6	-2.2
1968-1976	5.6	4.3	2.3	1.5
1960-1981	3.3	1.6	1.4	0.6
1970-1981	2.2	2.1	0.5	-0.2
1968-1981	3.7	3.0	2.7	2.3
1977-1981	-0.9	-0.2	2.3	2.8

	Quebecair		EPA	
Period	CRO/TFI 1	CRO/TFI 2	CRO/TFI 1	CRO/TFI 2
1960-1976	3.4	2.1	2.3	1.1
1960-1968	1.8	2.0	-2.2	-2.2
1968-1976	5.0	2.3	7.0	4.6
1960-1981	3.3	2.4	1.7	0.8
1970-1981	3.2	1.8	2.0	0.8
1968-1981	4.3	2.7	4.2	2.7
1977-1981	2.0	2.4	-1.7	-1.8

A PRODUCTIVITY STUDY OF
CANADIAN AIR CARRIERS

by

Roger Roy

and

Diane Cofsky

CANADIAN TRANSPORT COMMISSION
Research Branch
Economic and Social Research Directorate
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PREFACE

This paper entitled "A Productivity Study of Canadian Air Carriers" examines the performance of the seven major air carriers over the period 1960 to 1981. The carriers analyzed are Air Canada, CP Air, Pacific Western Airlines, Transair, Nordair, Quebecair and Eastern Provincial Airways.

The text begins with a review of the growth of the air transport industry in Canada. A description of methods and data used to measure the productivity of Canadian air carriers follows. The report, then, examines the performance of the carriers under various measures of productivity.

The paper was prepared by Roger Roy and Diane Cofsky of the Economic and Social Research Directorate. The authors acknowledge with gratitude the comments of Dr. George Hariton, Dr. Kenneth Mozersky, Mr. Richard Fosbrooke, Dr. John A. Greig, and Mr. John Gibberd, at various stages of their research, which were all very valuable.

This report is released as a contribution to the public discussion of the important issue of productivity in the Canadian airline industry. However, the opinions expressed are those of the authors and do not necessarily reflect the views of the Canadian Transport Commission.

Yves Dubé
Vice-President (Research)

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SUMMARY AND CONCLUSIONS

The objective of this paper is twofold. First it quantifies the recent productivity performance of Canadian airlines by updating an earlier CTC study. Secondly, the paper investigates the applicability of recent developments in the index number theory which allows comparative analysis of gains of various airlines. The various measures based on different index number approaches were estimated with data from the seven major carriers in Canada: Air Canada, CP Air, Pacific Western Airlines (PWA), Transair, Nordair, Quebecair and Eastern Provincial Airways (EPA). By the end of 1979 Transair merged with PWA, leaving only six carriers for the last two years of the period under study, which is 1960 to 1981. The sources of growth and differences in both output and levels of productivity were investigated in this study.

Measures of the following eight types of output were retained: First Class Passenger Service, Economy Class Passenger Service, Freight, Mail, Excess Baggage, Express, Bulk (Charter) and Specialty Flying. Two additional measures of output were used for Air Canada and CP Air. Thus, available seat-miles and available ton-miles were also used to measure airline activity with regard to the transport of passengers and goods, respectively. An aggregate output index was computed by weighting each physical measure of output by its relative share in total revenue.

Labour input comprises six categories of employment, which are measured in person-years and weighted by their share of total labour costs. The three other inputs of productivity analysis are material, fuel and capital. Material covers all inputs other than fuel, capital and labour. Material input, given its heterogeneity, is measured in constant dollars and then converted to an index. Fuel is not included in material but forms a separate category given its impact on production costs. The different types of fuel used were all converted to British Thermal Units (BTU's) prior to aggregation. Three measures of capital input were made. The first measure was based on the number of aircraft, the second on the number of aircraft hours flown and the third was an aggregate measure in terms of aircraft ton-hours flown.

The above factors were combined to provide measures of total factor productivity of the airline industry. Under the Divisia approach, the total factor productivity indices show a marked recent slowdown in air transport productivity gains. Between 1977 and 1981, PWA and EPA saw their inputs grow on the average more rapidly than their outputs. This resulted in negative productivity for these two carriers. Quebecair and

Nordair, on the other hand, experienced productivity improvements over the same years. Those gains have been related to the nature of their operations, as the two carriers offered a diversity of services that took full advantage of the complementarity of those services.

ANNUAL PERCENTAGE RATES OF GROWTH OF FACTOR PRODUCTIVITIES

Period	Air Canada	CP Air	PWA	Nordair	Quebecair	EPA
1960-1976	3.4	5.6	1.7	0.9	-0.3	2.1
1977-1981	0.3	1.7	-0.2	2.8	2.4	-1.8
1960-1981	2.9	4.8	1.6	0.6	2.4	0.8

Further analysis showed that the more moderate increases in output over the 1977-1981 period were attributable in a large part to quantitative changes in utilization of the inputs. Qualitative improvements in equipment no longer translate into growth of production but rather into improved utilization of production factors.

The Divisia approach measures productivity changes for each airline but does not allow productivity comparisons among airlines. The translog multilateral approach, also used to measure the total factor productivity of Canadian air carriers, made it possible to measure productivity in relative terms and compare the performances of the carriers. Using this approach, the three carriers that appear to have scored the best performances are CP Air, Air Canada and Quebecair. Under the Divisia approach, these same airlines also chalked up the most noteworthy productivity improvements.

Using an analysis of covariance, an attempt was made to identify the sources of variation in productivity measured under the multilateral translog approach. For the period 1960-1981, the covariance analysis sought to determine whether output, average stage length, average aircraft ton-hours flown, load factor and binary variables representing firms and years are indeed variables that explain the observed productivity variations. The results do not support generalizations with respect to the decomposition of total factor productivity, as the results are unstable from one year to the next.

Further insights into productivity changes are provided by partial productivity indices, which show the manner in which each factor input affected output. All airlines showed improvements in labour productivity; for Air Canada and CP Air, labour productivity gains were lower in the seventies than in the sixties while the opposite was true for the regional airlines. Capital productivity increased rapidly when jets were introduced in the sixties, but slowed down thereafter. Newer developments of energy-efficient aircraft tend to lead to increased energy productivity instead. Finally, material productivity has been negative in recent years.

INTRODUCTION

Productivity improvement has been identified as a helpful, if not necessary, condition for an industry to develop a record of growth. Certainly, productivity improvement is not a sufficient condition for the achievement of a growth but it does nevertheless help an industry to keep pace with the evolution of other industries.

The recent evidence suggests that productivity has been growing at a significantly slower rate. According to Denny and Fuss (1982), "there is no doubt that widespread declines in the rates of productivity growth have been common in Canadian industries".

Average annual real output growth of the Canadian economy from 1960 to 1981 equalled almost 4.5%. From 1960 to 1976, annual real output growth averaged 5.1%, compared to only 2.7% for the period 1977 to 1981. Thus, in recent years, real output has been growing at a much lower rate. By comparison, the Consumer Price Index grew at an average annual rate of 5.0% between 1960 and 1976 and at an average annual rate of 9.2% between 1977 and 1981, resulting in an average of growth of 5.9% for the entire period from 1960 to 1981. These economy-wide results form the background against which changes in the performance of the Canadian airline industry should be considered.

At the present time, there is a growing interest in productivity because of the effects of the recession on the airlines' traffic whose growth has slowed or declined since the end of the seventies.

In addition, the Canadian air transport industry is regulated. This generates additional interest in measuring and improving productivity. Decisions to be made about the industry by regulators often require information on productivity. For example, information on productivity is helpful in decisions on fares and rates for air transport services. It is necessary to monitor the productivity performance of regulated firms in order to prevent a regulatory actions approach from weakening the industry's incentives to improve productivity.

The fundamental problems of productivity measurement are developing acceptable measures of the basic rates of growth and determining the weights to be attached to the different factor inputs. For a number of reasons, these measurement and weighting problems are often resolved frequently with a certain number of assumptions and judgments. On the output side, several measures of output are needed to accurately reflect all the relevant dimensions of air carrier output. These different measures have to be combined to create one composite index of total output. A major difficulty encountered in measuring air carrier output is the problem of controlling for differences in the quality of service rendered. Complications also arise in determining the factor inputs required for delivering air transport services. For instance, one of the important difficulties is that the carriers do not own outright some of the capital they use (e.g., airports and airways).

This paper constitutes firstly an update of an earlier study and, secondly, an exploration of different ways of measuring productivity. It updates to 1981 the estimates of productivity trends in the Canadian air transport industry. Therefore the productivity estimates cover the 1960 to 1981 period. The carriers under study include the seven most important in Canada, namely Air Canada, CP Air, PWA, Transair, Nordair, Quebecair and EPA.

The paper is organized into five chapters. The first chapter gives a picture of the environment in which the Canadian airline industry was operating during the 1960-1981 period. The second chapter addresses concepts, methodology and data used in the empirical investigation. Chapters 3 and 4 present an extensive discussion of the recent productivity slowdown in the Canadian air transport industry. Productivity growth is first estimated with Divisia indexes. Then, in Chapter 4, the relative levels of Canadian air carriers' productivity are estimated using an index-number approach, known as the multilateral index. In addition, both chapters investigate the sources of the slowdown. The focal point of interest in Chapter 4 stems from the fact that it concentrates on a subject of perennial interest: inter-carriers comparisons of productivity. The recent lagging in productivity growth is clarified by being described in historical perspective. The measurement of productivity in terms of partial measures of productivity is the topic of the last chapter. Such measures relate output to one input at a time.

Chapter 1

A HISTORICAL REVIEW OF THE EVOLUTION OF CANADIAN AIR TRANSPORT

CP Air and Air Canada are Canada's two major air carriers, operating on the domestic mainline system and on international routes. Together, they accounted for 87% of the Canadian air transport industry in 1981 when such activity is measured in terms of passenger-miles performed. The major portion of their activity was devoted to passenger traffic, as compared with goods and charter traffic for the regional airlines.

The regulation limiting competition between CP Air and Air Canada has been amended considerably since 1960. In the beginning Air Canada held a monopoly on mainline traffic in Canada. The regulatory provisions gradually eased and CP Air* was given entry on a controlled basis to the Vancouver-Winnipeg-Toronto-Montréal trunk. This policy change grew out of the recommendations of Wheatcroft's 1958 study. Subsequently, CP Air was authorized to add another daily flight in 1967 and in 1970 was permitted to expand its activity to 25% of the traffic on the segment in question. In 1974, CP Air was freed from the restriction that all its flights originating in Vancouver must terminate in Montréal. In 1977, CP's authorized share of the market was increased slightly through greater participation in the growth of traffic, to 35% of that growth in 1978 and to 45% in 1979. On March 23, 1979, the government authorized Air Canada and CP Air to compete freely in the Canadian market. CP's market share reached a maximum of 35.3% in December 1981 and has remained fairly stable.

Canada's two major airlines do not generally compete on international markets. Figures 1 and 2 illustrate the international markets served by each airline.

If, in sum, Canada's two mainline carriers operate basically non-competitively in the foreign markets, in contrast, a certain form of competition has developed in recent years on some of the domestic mainline routes.

Technologically, the greatest change in the airline industry between 1960 and 1981 was the advent of jet aircraft.

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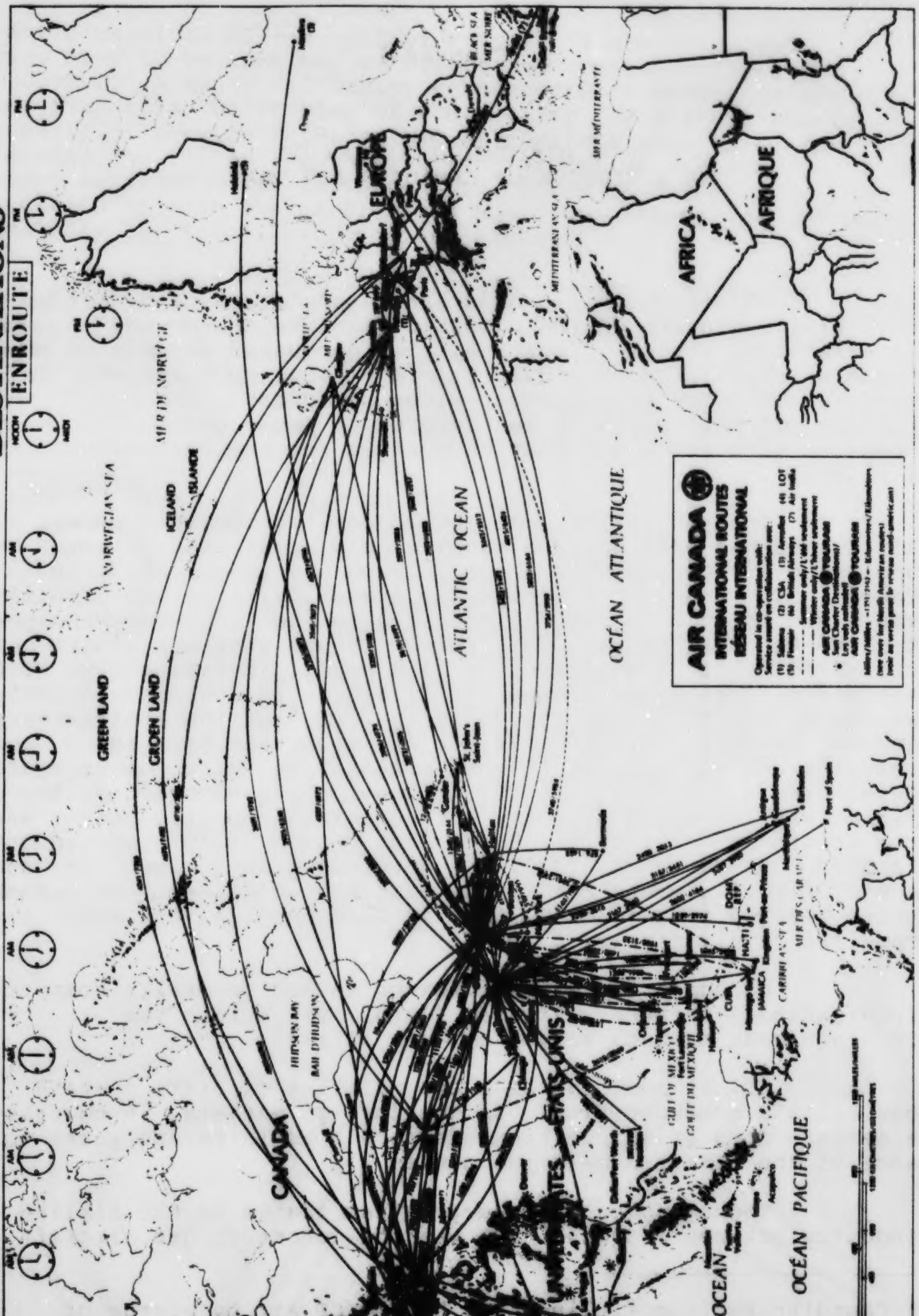
* Canadian Pacific Airline Ltd. became CP Air by virtue of decision no. 6063, February 25, 1980.

Figure 1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INTERNATIONAL ROUTES
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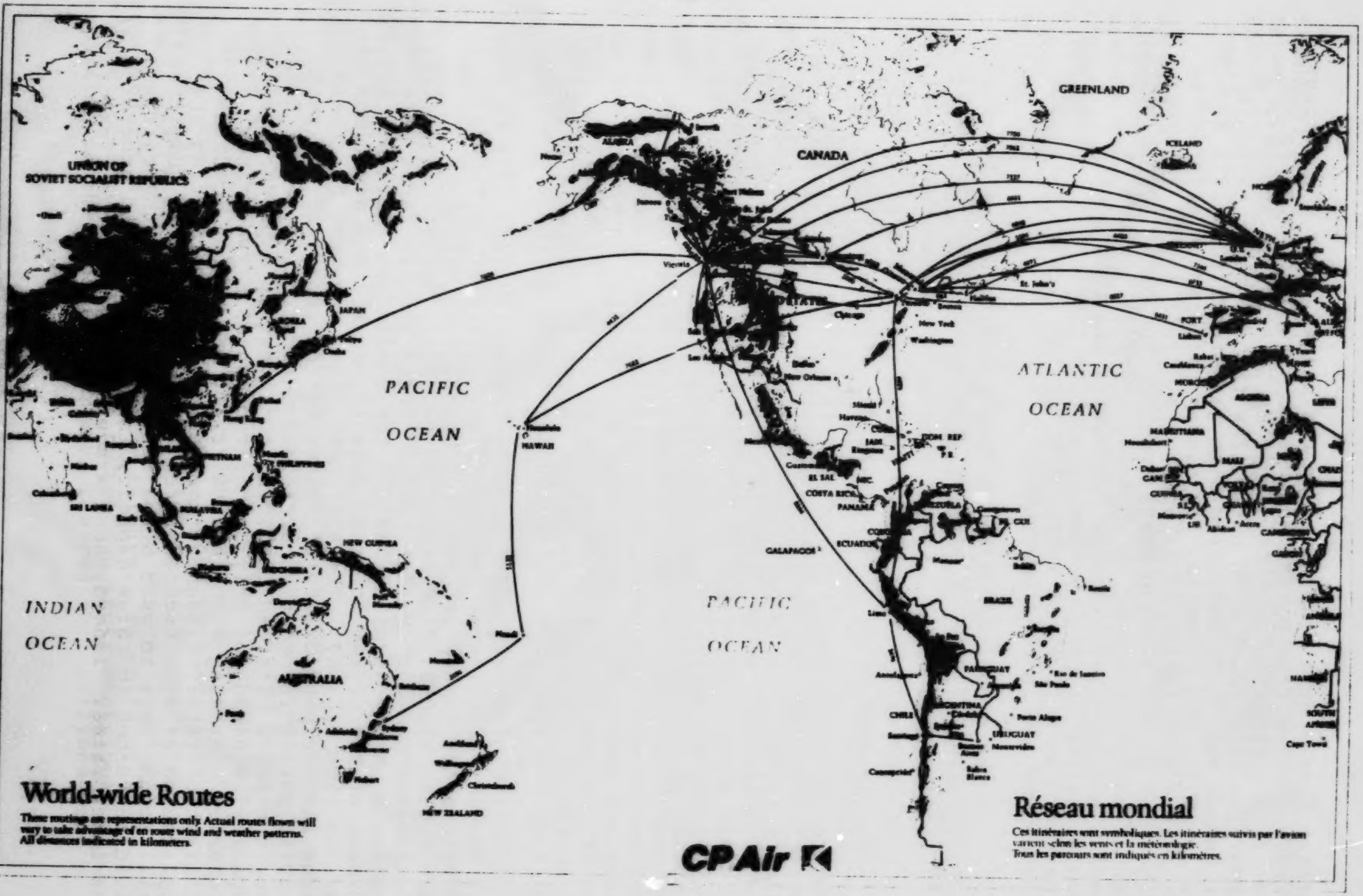
Figure 2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Montevideo
Rio de Janeiro
São Paulo
Porto Alegre
CHILE
Santiago
Concepción
ARGENTINA
MAURITANIA
Cape Town
SOUTH AFRICA
CP Air

World-wide Routes

These routings are representations only. Actual routes flown will vary to take advantage of en route wind and weather patterns. All distances indicated in kilometers.

Réseau mondial

Ces itinéraires sont symboliques. Les itinéraires suivis par l'avion varient selon les vents et la météorologie. Tous les parcours sont indiqués en kilomètres.

Airline fleets were modernized in two stages, with the carriers first switching from piston engines to turboprop machines and then from turboprops to jetliners. Table A.3.1 in Appendix A summarizes this transition period for the two major carriers. Air Canada was fully outfitted with jet aircraft in 1974 and CP was in 1970. The potential for higher performance afforded by jet aircraft is reflected in average aircraft speed, take-off weight and longer average stage length. The other technological innovations contributing to improved services include specialization of maintenance facilities and practices, specialization of cargo movement, computerization of booking and financial operations and improvement of the airport terminals provided by the federal government.

The production data in Tables D.5 to D.7 of Appendix D highlight the strength of airline development over the period 1960-1981.

The rapid rise in fuel prices since 1976 prompted airlines to seek means of economizing. British Airways, for one, estimated that each kilogram of dead weight on a Boeing 747 was costing it $450 a year, 20% of that in additional fuel. A carrier that operates some 20 aircraft daily has everything to gain by trying to eliminate dead weight. Measures conducive to reducing aircraft weight include minimizing the storage of drinking water, the weight of the seats, kitchen equipment, partitions and carpeting, as well as lightening the weight of the exterior paint and thus lessening friction. In 1981, Air Canada was the world leader in air transport technology owing to its performance with respect to maintenance and management of its fleet and operations. It was also acknowledged as having set up one of the best energy conservation programs. From 1977 to 1979, it scored an average 14% reduction in overall energy consumption, while at the same time increasing the volume of its operations.

Another key event marking the period from 1976 to date was the introduction of reduced fares. Starting in February 1977, the Air Transport Committee handed down decisions authorizing special fares known as Canadian Charter Class (CCC) and Advance Booking Charter (ABC). These special fares were available on a controlled basis. The conditions included partial payment of the ticket 60 or 45 days in advance and a minimum or maximum time of stay. The airlines' chief argument for these fares was the possibility of lessening the impact of the peak traffic period in order to achieve a more stable level of demand over the year. Instead of having to invest in a productive capacity required for only one or two months a year, they preferred operating with fewer aircraft but higher loads and utilization rates throughout the year. While permitting the application of such reduced fares, the Air Transport Committee still sought ways to ward off a situation wherein the carriers would be forced to raise capacity to meet the demand generated by the lower rates. Indeed, such a scenario carries the risk of financial losses since traffic benefiting from these advantageous fares generates revenue that barely covers the marginal cost of the service. To prevent such a situation, the Committee set itself up as a watchdog.

The carriers themselves took certain precautions to safeguard their market segment. The main requirements were advance payment of all or part of the ticket price, a preset minimum stay, return-trip booking, cancellation fees and no changing of ticket conditions. Over the years, however, the carriers offered an increasingly diversified range of reduced fares. A brief chronology of the evolution of these arrangements follows.

On May 1, 1978, CP Air inaugurated its Courier Jet service, which required no advance booking. Shortly thereafter, Air Canada launched its Nighthawk service, which made use of specially reserved aircraft and required no advance booking.

On March 27, 1979, Air Canada and CP Air introduced a new concept: seat sales. This fare required advance booking and a minimum/maximum stay; it afforded passengers greater savings than did the Canadian Charter Class (CCC) fare. On June 1 of that year, CP Air introduced its Airbus service, which required no advance booking or preset time of stay.

Airline seat sales were subsequently offered six times, sometimes only by Air Canada and sometimes by both Air Canada and CP Air.

In February 1980, the ABC restrictions were eased and in May, Wardair began offering ABC's on its Canadian network. That same year CP Air cancelled its Courier Jet service but expanded its Airbus service, which was offered starting in October in the form of reserved sections on regular flights but only for specific city pairs. In June 1981, Air Canada and CP Air announced a new excursion fare on the transcontinental route and another reduced fare for certain city pairs served by Air Canada. These fares replaced the Canadian Charter Class (CCC), the seat sales and the Nighthawk services and were more constraining as a rule.

In the early sixties, the activity of the regional carriers — Pacific Western Airlines, Transair, Nordair, Quebecair and Eastern Provincial Airways — focused heavily on regular and scheduled air services on routes linking the major cities with secondary communities and remote regions of Canada. The main services typifying these airlines were services complementary to those operated by the mainline carriers, Air Canada and CP Air, flights on developing routes, local air services and a variety of charter flights. In spite of their strong presence on north-south routes and their contribution to expansion of the Canadian economy, the regional airlines were faced with problems of instability owing to seasonal and cyclic fluctuations. They also faced certain diseconomies stemming from the average length of their flights and low-density traffic for their local operations.

Tables D.5 to D.7 of Appendix D present revenue passenger-mile statistics allowing for comparison of the relative importance of the regional carriers with respect to Air Canada and CP Air. Unit-toll passenger traffic accounts for the major portion of the revenues of the two major airlines, whereas goods and charter transport prevails for the regional carriers.

In 1966 the Honourable J.W. Pickersgill, Minister of Transport, defined a new policy applicable to the five regional carriers. The essence of that policy is summed up in the four points below.

(1) Limited competition was allowed on Air Canada and CP Air trunks when compatible with the local development of these routes.

(2) Air Canada and CP Air could transfer routes to regional carriers in some cases.

(3) The regional carriers were granted a broader role in the development of domestic and international charter services.

(4) Increased technical cooperation among carriers was allowed in the areas of maintenance, repair and joint fares.

In 1969 the Honourable D. Jamieson, Minister of Transport, reaffirmed regional air carrier policy and defined more specifically the regional carrier zones of operation. They were:

(1) for PWA, British Columbia and western Alberta;
(2) for Transair, the Prairie Provinces and northwestern Ontario;
(3) for Nordair, the remainder of Ontario and northwestern Quebec;
(4) for Quebecair, all of Quebec east of Montréal; and
(5) for EPA, the Atlantic Provinces.

Basic changes affecting the regional airlines since 1970 include the 1974 purchase of PWA by the Province of Alberta. In 1977, Alberta made an offer to purchase the majority of shares in Transair and on April 7, 1978, the transaction was completed. On August 9, 1979, Transair was fully merged with PWA. In early January 1978, Air Canada announced plans to purchase the majority of shares in Nordair and the Canadian Transport Commission voiced no opposition.

On the technical side, jet aircraft were introduced into regional carrier fleets in 1967 when PWA first used this type of aircraft. By 1970, all of the regional airlines were using jets, which in 1976 accounted for 83% of their overall ton-hours performed.

Since 1976, a number of changes have had major impact on regional airline development. On March 29, 1979, Nordair was authorized to serve Toronto and Ottawa from Québec. That May 1, it inaugurated its Montréal-Toronto route. These routes are particularly important, as they are high-density trunks of the Air Canada and CP Air mainlines. On January 12, 1981, Quebecair and PWA were given permission to add Toronto to their itineraries. These examples show how important implementation of the 1966 policy has been for the regional carriers, allowing them some degree of competition with the majors, Air Canada and CP Air.

Chapter 2

METHODS AND DATA

2.1 Measures of Productivity

Productivity is the relationship between output(s) and associated inputs used in the production process. The conceptual framework for the measurement of productivity comes from the economic theory of production. This theory underlies the measurement of both changes in productivity over time and differences in productivity among firms producing similar output. Without going into the details of the economic theory of production, its main features will be summarized in order to explain the rationale for the weighting procedures used to aggregate various types of output and input.

At the level of the firm, the quantity of output is a function of the quantity of services of the basic factors of production used. The factors of production can be grouped into three categories: labour and capital plus the intermediate products purchased from other firms. The last variable affecting the quantity of output produced is the level of productive efficiency and this level changes over time. This variable is what we are trying to measure.

In the case of airline operations, fuel is one intermediate product which is important enough in terms of annual expenditures to justify its distinction from the other intermediate products needed to produce air services. Input variables are aggregations of various components.

Output and input measures can be related in two different ways to arrive at productivity measures. First, the ratio of output to individual classes of input can be calculated. Such ratios are known as 'partial' productivity measures. The second type of productivity measure is known as a 'multifactor' productivity measure or 'total' factor productivity measure, consisting of the ratios of output to all associated inputs. The utility of each measure is somewhat different.

Partial productivity measures are useful in showing the savings achieved over time and/or between firms in the use of each input per unit of output. A change in a partial productivity measure reflects both a change in productive efficiency and factor substitutions resulting from changes in relative factor prices. In more technical words, when partial productivity changes are observed, they reflect either a movement along a production function as factor proportions are changed and/or shifts in production functions due to technological change.

Changes in total factor productivity measures are associated with the net savings in the real costs of production achieved over time. Therefore a change in total factor productivity is associated with a change in productive efficiency when all inputs are included in the denominator. Cost-reducing technological progress constitutes one of the main sources of increases in total factor productivity if comparable rates of capacity utilization are observed between firms and/or over the years. For authors like Diewert (1981), total factor productivity and technical progress are the same basic concept. (For a survey of the methods currently used to measure total factor productivity, see Appendix B.)

Increases in partial factor measures may simply reflect the substitution of one input for another, rather than purely technological advancement. Therefore, the use of total factor productivity measures, which relate changes in output to changes in all inputs, yields a more accurate measure of productivity advancement. Changes in the growth rates of total factor productivity measures are due to non-input sources such as technical change, managerial innovations, improved resource allocation, etc. Nevertheless, partial factor productivity measures are useful in interpreting the reasons for changes in total factor productivity.

Total factor productivity measures imply not only the combination of various input quantities but also the combination of various outputs. The aggregation of outputs and inputs uses a methodology with weights. These weights find their justification in the economic theory of production. That theory assumes that producers minimize their costs and that competitive conditions prevail in both factor markets and product markets. Such assumptions imply two things. First, that producers use each input to the point where the value of its marginal product (i.e., the increase in output associated with the use of an additional unit of the input) is equal to its cost per unit, i.e., its price. Second, that outputs are produced up to the point where their unit cost, which include a normal profit, are equal to their price, exclusive of indirect taxes. In terms of the weights used in productivity measures, these assumptions explain why product prices for a base period are normally used as weights to combine various output quantities and base-period input prices to weight inputs.

If the assumptions which justify the utilization of such weights are not verified, the methodology gives biased results. It is important to note that the type of weighting scheme used is determined by the precise mathematical form of the production function used for measuring outputs and inputs. The form of the production function is not only relevant to the weights by which the inputs and the outputs are combined to obtain aggregates but also to the interpretation of the results.

Some economists have argued that if outputs and inputs could accurately be accounted for, the observed growth in total factor productivity would be negligible. As a result, the literature on TFP is mainly devoted to problems of measurement and hardly address the problems of explanation, so much so that TFP has been given such labels as "the residual" or "the measure of our ignorance".

Productivity performance of major Canadian air carriers was measured using Tornqvist approximation to the Divisia index. Multilateral indexes were also used for carriers' productivity comparisons. Technical details on the multilateral indexes are provided within Appendix E. Under both approaches, revenue shares are used as weights for outputs which imply constant returns to scale for the structure of production.

The assumption that production exhibits constant returns to scale is suitable perhaps for an industry-wide study relying on national income data. However, at the firm level, this assumption is debatable. If technical change is a source of economic growth, a study of an industry's performance should not neglect another important source of growth which is economies of scale. Therefore, rather than maintaining a hypothesis with respect to returns to scale, one should test the type of returns with the model of economic growth. In general, failure to adjust for increasing (decreasing) returns to scale yields an overstatement (understatement) of total factor productivity growth. (For details see Appendix C.)

By selecting the Divisia index approach to measure TFP, implicitly it was assumed that airlines were facing constant returns to scale in their operations. Appendix C shows that such a maintained hypothesis implies that technical change is measured by total factor productivity. It was said previously that it is preferable to test the type of returns in order to properly interpret the TFP growth. A CTC study* has offered insights on the scale effects within the air transport industry in Canada. This study has modelled the structure of production of Canadian airlines. In order to estimate the underlying technology of Canadian air carriers' operations, cost functions were estimated. Cost functions, instead of production functions, were estimated to picture the underlying technology for matters of statistical convenience and for analytical purpose.

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* Roger Roy, Economies of Scale in the Airline Industry, Canadian Transport Commission, Research Report No. 10-80-06E, June 1980.

The CTC study on economies of scale concluded that airline technology in Canada exhibited constant returns to scale over the period 1968-1977:

> "The evidence on scale economies obtained from the estimates in this study is not sufficient to reject, for the Canadian airline industry, the evidence of constant returns to scale arrived at by air industry researchers analyses." (p.80)

Therefore the Divisia index approach is a defensible method to use in a productivity analysis of the Canadian air transport industry. It should be added that global characterization of the relationship between costs and operating characteristics is not possible. Thus, changes in costs with respect to operating characteristics of carriers differ depending upon the level of factor prices, output, and/or other variables.

Technological change and economies of scale can only provide a useful knowledge on the broad patterns of contributions to growth and they tell relatively little about the more detailed aspects and patterns of growth. For example, the existing productivity measures do not allow one to quantify the relative importance of new products and/or service innovation (seat sales, etc.) in total innovation.

Airlines are capital intensive in their operations. Therefore, relatively small differences in capacity-utilization rates (e.g., the average rate of capacity utilization to maximum capacity) can result in substantial differences in required capital inputs. The existing data did not allow one to account for the degree of capacity utilization in the productivity measures.

Institutional factors also affect productivity change in an industry like the air transport industry, and, yet, it is not possible to measure accurately the importance of such factors. Recently, total factor productivity measures have been specified to account appropriately for effective rate-of-return regulation. But, this is not the only institutional restriction faced by firms.

2.2 Data

This section describes the data used to calculate the productivity indices. The description is intended to highlight the problems of definition and aggregation and, more simply, the problems of measurement underlying productivity analysis of a sector such as air transport.

2.2.1 Measurement of Output

The airline industry produces several types of output. The calculation of an index that takes all of these outputs into account supposes first their identification, then the determination of appropriate units of measurement and finally the aggregation of the outputs to reflect their relative size in overall production. Eight types of output were identified and retained: First Class Passenger Service, Economy Class Passenger Service, Freight, Mail, Excess Baggage, Express, Bulk (Charter) and Specialty Flying. The first two types of output were measured in revenue passenger-miles. Everything relating to the transport of goods was measured in revenue ton-miles. This includes mail, excess baggage and express. The unit of measurement for charter services was dictated by available data; all measurements were in terms of aircraft miles performed. The unit of measurement for specialty flying was aircraft hours performed.

As with the previous productivity study (1978), it was possible to use another measure of output for the scheduled services of Air Canada and CP Air. The regular passenger transportation activity of these two carriers was measured in terms of available passenger-miles, whereas scheduled goods traffic was calculated in terms of available ton-miles. Specialty flying (aerial photography, crop dusting, etc.) is not offered by all of the airlines. PWA, for one, operated no specialty services in 1977.

The index of aggregated outputs was calculated under the two approaches, the Divisia approach and the multilateral approach, by weighting each output by its share in total revenue. The resulting index can be standardized around a desired point. Under the Divisia index approach, the year 1960 served as the base year for each carrier, the 1960 index being equated to 100.0. Under the translog multilateral index approach, standardization centred around the value of the index for a given year and carrier. In the case of grouped data, one must select a point representing a given year for one of the firms under review. For a study of Canada's major air carriers between 1960 and 1981, the year 1977 provides the highest level of neutrality for PWA and is thus a point apparently best suited for standardization. However, as was said earlier, PWA operated no specialty services in 1977. This makes it impossible to standardize the physical measures of output prior to calculating the output index under the translog multilateral approach when attempting literal application of the approach of Caves, Christensen and Tretheway (1982) to the Canadian context. Standardization is not feasible since there is no "representative" year in which all types of output were produced by an airline "representative" of the evolution of the industry.

The two approaches used to calculate the aggregate output index entail methodological differences, as illustrated in the Appendices. These methodological differences are at the source of the dissimilarities observed in the indices computed under these two approaches. More will be said about these dissimilarities further on. A descriptive analysis of the output trends observed between 1960 and 1981 is presented in Appendix D.

2.2.2 Measurement of Labour Input

Labour input is measured by a composite index called in this study the Composite Labour Input Index (CLI). This index covers the following six categories of employment: Pilots and Co-pilots, Other Flight Personnel, General Maintenance and Administration, Maintenance Labour, Aircraft and Traffic Servicing and Other Employees.

Under the multilateral approach, the six labour categories are aggregated into two classes: the first class comprises the first two labour categories and the second class comprises the remaining categories. Labour input was therefore uniformly aggregated under this approach for the study period of 1960 to 1981. The Divisia approach, on the other hand, uses a Divisia index to measure labour input. Each category of employment is measured in terms of person-years, as with the other approach, and is weighted by its relative share of total labour costs. As data quality varied for certain carriers over the period, some labour categories had to be grouped with others for certain years in order to preserve a high degree of reliability for the measurement of this input.

It is necessary to adjust the total employment data for labour strikes if the employment to hour ratio is to remain valid. The major labour strikes along with the person-days lost are presented in Table 2.1. Only the major 1969 strike of Air Canada required adjustment, as the airlines had already adjusted their employment data prior to reporting to Statistics Canada or else the difference was not perceptible.

2.2.3 Material Input

The inputs surveyed under what is referred to here as "material" include a diversified range of products and services, among them light, heat and power, office supplies, passenger meals, advertising services and landing fees.* They accounted for an average of 34% of total costs over the 1960-1976 period, with the average share of the material input dipping to 33% for the 1960-1981 period. Purchase costs for material input were measured in constant 1971 dollars, having been deflated by the

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* Landing fees should strictly be included under capital input since they are expenditures incurred for utilization of airports.

Table 2.1

MAJOR LABOUR STRIKES, CANADIAN AIRLINES AND MINISTRY OF TRANSPORT, 1960-1981

Year	Airline	Worker Category	Person-days Lost
1963	PWA	Traffic employees	3 210
1966	Air Canada	Machinists	49 336
1969	Air Canada	Machinists	131 120
1971	Air Canada	Machinists	12 600
1972	Ministry of Transport	Air Traffic Controllers' Association	14 400
	Ministry of Transport	I.B.E.W.	30 930
1973	Nordair	Machinists	11 110
	CP Air	Machinists	54 060
	Air Canada	Canadian Airline Employees Association	22 000
	Air Canada	Machinists	16 200
1974	Air Canada	Machinists (various locals)	3 180
1975	Transair	Machinists	19 970
1976	Air Canada	Canadian Airline Employees Association	14 280
	All airlines	Canadian Air Line Pilots Association	17 000
	Ministry of Transport	Inspectors	1 830
	EPA	Air Transport Employees	1 990
1977	Air Canada	Machinists	100
	Ministry of Transport	Canadian Traffic Controllers' Association	6 600
1978	PWA	Air Transport Employees	9 830
	Air Canada	Machinists	58 930
	Nordair	Canadian Air Line Pilots Association	250
	Quebecair	Machinists	3 710
1980	Transport Canada	Air Traffic Controllers' Association	200
1981	Quebecair	Machinists	640
	Nordair	Airline Flight Personnel	2 730

Source: Strikes and Lock-outs, Employment and Immigration Canada.

Personal Expenditure Component of the GNE Implicit Price Index. These costs were then converted to indices.

Fuel, given its significance in operating costs, was not included in the material input.

2.2.4 Fuel Input

Fuel accounted for about 13% of total annual costs over the period 1960-1976, with the average rising to 16.5% when the study period extends to 1981. Given frequent fuel cost hikes in recent years, this input currently plays a major role in the technological development of aircraft and thus in airline productivity. In fact, increasing fuel costs have recently been such that aircraft manufacturers have been forced to seek ways to improve the energy efficiency of the machines on the market. Recent developments in aircraft construction allow for fuel savings, which carriers eagerly seek to enhance their performance.

The airlines used several types of fuel: kerosene, naphtha and aviation gasoline. It is preferable to consider the energy content of these fuels rather than the quantities expended. In light of this, the fuels were all expressed in British Thermal Units (BTU's)* and then summed to give a measure of total fuel input.

2.2.5 Capital Input

Capital input encompassed all airport facilities, aircraft, passenger and traffic servicing equipment, maintenance equipment, buildings, rental payments on leased aircraft, etc. The heterogeneous components of capital can be handled by expressing them all in constant-dollar values or in single physical measurement where possible. Given, however, that aircraft are the predominant component of the airlines' capital investment in the production of air services and that landing fees have already been accounted for in material input, only aircraft were taken as the measure of capital stock.

The bias which this computational method entails will be nil if the aircraft to total capital ratio remains constant over time. Even given a slight fluctuation in this ratio, the share of aircraft in capital is so dominant that the bias will remain minimal.

Whereas more than one measurement of capital was used in this study, all of them focused on the fleet of the airlines.

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* Conversion Factors: 147 000 BTU's per gallon for turbo fuel
133 500 BTU's per gallon for aviation gasoline.

There is more than one means of reckoning with the importance of aircraft in an airline's production process, and three such means were retained here. Aircraft productive capacity is first a function of the carrier's stock of machines. Thus, one measure of capital consists in simply considering the number of aircraft making up the carrier's fleet. This type of measure does not adequately reckon with aircraft productive capacity or utilization. A second measure of capital input takes the total number of aircraft hours flown annually by each carrier. This unit of measurement is related to the capital flow. Aircraft hours flown are primarily linked to the utilization aspect of the aircraft which produced such flight hours. This opened up the possibility of using a third measure of capital input whereby the aircraft ton-hours per annum is taken as the unit, making it possible to consider both aircraft size and utilization.

Obsolescence caused by the arrival of new and better machines and depreciation over time are two factors prompting a decline in the value of older aircraft. In spite of this, the depreciation rate for jet airliners has remained very low.* Given this, as well as expert opinion confirming that the decline in the production capacity of an aircraft over the years is quite low, it was decided to assume a zero depreciation rate and to take the above measures of aircraft as representative of capital.

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* For a detailed discussion of this point, see the preceding study: P.S. Dhruvarajan, R.F. Harris and others, A Productivity Study of the Canadian Airline Industry, Canadian Transport Commission, Research Branch, Research Report No. 10-78-03, March 1978.

Chapter 3

TOTAL FACTOR PRODUCTIVITY: DIVISIA INDEX APPROACH

Total factor productivity measures represent a more comprehensive approach to the measurement of productivity than partial measures. Partial measures are simply ratios of a measure of aggregate output (or of an index of aggregate output) divided by the observed quantity of a single input (or by an index of a given input). (Appendix B presents a survey of total factor productivity measures.) In simple terms, total factor productivity indexes consist of the ratio of two separate indexes, one for outputs and one for total inputs. The output index is a weighted measure of heterogeneous joint outputs. Two composite Divisia index measures of airline's total output were used. In both cases, the composite output covers passengers, goods, bulk output and specialty flying. The physical output measures already described in the previous chapter for the four output types are combined on the basis of their revenue shares in the airline operations. If, for passenger output, available seat-miles are used together with the availability measure of ton-miles for goods transport, the composite Divisia index obtained is named Composite Available Output (CAO). When the output measures used are revenue passenger-miles and revenue goods ton-miles then the Divisia index is named Composite Revenue Output (CRO). The CRO indices were calculated for all the carriers while the CAO indices could only be estimated for Air Canada and CP Air.

The input measure includes all inputs used in the production process. Labour, capital, fuel and material were combined using a Divisia index to derive the Total Factor Input (TFI). Two measures of total factor input were calculated, the first one using aircraft hours as the measure of capital (TFI 1) and the second one measuring capital in terms of aircraft ton-hours (TFI 2). Therefore, total factor productivity was measured as either CRO/TFI 1 or CRO/TFI 2. For Air Canada and CP Air, two extra measures of total factor productivity were derived: CAO/TFI 1 and CAO/TFI 2.

Total factor productivity measures are a distinct improvement over partial measures in that changes in all inputs, conceptually, can be accounted for. However, as previously said, total factor productivity measures do not solve the difficulties of disentangling technical change from the effects of scale economies, an issue which is important but not critical in the case of the Canadian air transport industry.

3.1 Total Factor Productivity

The Divisia index methodology used to provide estimates of the levels of total factor productivity (TFP) is defined briefly in Appendix B and in more detail in Appendix C. It should be emphasized that TFP indexes were computed using the discrete approximation to the Divisia index. The Divisia index number approach was used to study the productivity of seven Canadian carriers during the period 1960-1981. Two years, 1980 and 1981, were omitted for Transair because of its merger with PWA. Section 2.2 contains a description of the methods used in the construction of the data set, along with a definition of the different variables.

TFP indexes were estimated for the Canadian air carriers. Surveying the historical growth in productivity for individual carriers between 1960 and 1981 provides perspective for that industry's performance during recent periods. It makes it possible to present a recent short-run picture of the carriers' performance pattern. Because Air Canada and CP Air are the only two carriers for which it was possible to measure productivity in terms of Composite Available Output (CAO), these two carriers' performance will first be analysed.

In the earlier productivity study,* it was found that the relationship between factor productivity and available output was indicating a "much lower rate of increase in the seventies than ... in the sixties". Looking at the annual rate of increase in productivity in terms of available output between 1977 and 1981 upholds that statement. In fact, the rate had become negative for Air Canada and zero for CP Air (Table 3.1).

When related to Composite Revenue Output (CRO), Air Canada and CP Air productivity also underwent an extremely sharp decline in their productivity growth rates. Such an empirical finding is not reassuring. Without entering into an overly complex explanation of recent developments which could be responsible for this recent downward pattern, the core of the attention should be focused on the increase, in recent years, in the usage of materials by these two carriers in their production process. This is not to say that material is the only determinant of the recent level of productivity attained by Air Canada and CP Air. The next section will present a decomposition by sources of the output growth and will address in detail the issue.

Since Transair merged with PWA at the end of 1979, Transair will be excluded from the analysis of the regional

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* P.S. Dhruvarajan, R.F. Harris and others, A Productivity Study of the Canadian Airline Industry, Canadian Transport Commission, Research Report No. 10-78-03, March 1978.

Table 3.1

ANNUAL PERCENTAGE RATES OF GROWTH OF FACTOR PRODUCTIVITY
Air Canada and CP Air

Air Canada

Period	CAO/TFI 1	CAO/TFI 2	CRO/TFI 1	CRO/TFI 2
1960-1976	5.9	4.5	4.9	3.4
1960-1968	7.3	5.6	5.4	3.7
1968-1976	4.6	3.4	4.4	3.2
1960-1981	4.6	3.4	4.0	2.9
1970-1981	2.1	1.6	2.7	2.2
1968-1981	2.9	2.1	3.2	2.4
1977-1981	-0.3	-0.2	0.1	0.3

CP Air

Period	CAO/TFI 1	CAO/TFI 2	CRO/TFI 1	CRO/TFI 2
1960-1976	4.9	4.3	6.3	5.6
1960-1968	6.4	5.4	6.4	5.4
1968-1976	3.5	3.2	6.2	5.8
1960-1981	3.9	3.3	5.4	4.8
1970-1981	1.6	1.3	4.1	3.7
1968-1981	2.4	2.1	4.8	4.5
1977-1981	0.0	0.0	1.8	1.7

carriers' factor productivity. TFP indices for the regional carriers present two different patterns in the levels of productivity attained by these carriers (Table 3.2). On the one hand, PWA and EPA, between 1977 and 1981, have seen their productivity deteriorate to the point where their annual percentage rate of growth for their factor productivity became negative for those years. On the other hand, Quebecair and Nordair managed to maintain a positive rate of productivity change for the period 1977 to 1981. As a matter of fact, Nordair achieved a slightly superior productivity performance between those recent years than the one attained between 1968 and 1976. However, Quebecair's recent performance, when measured in terms of CRO/TFI 1, represents a reduction in the rate of productivity increase from the one observed between 1968 and 1976.

Surprisingly, Nordair and Quebecair, which experienced a productivity growth between 1977 and 1981, are the two carriers for which charter services represent an important activity in terms of revenue generated. An earlier CTC study stated that "there is some evidence of cost complementarities between unit toll operations and charter operations".* Such cost complementarities are associated with cost savings resulting from the simultaneous production of several different outputs in a single firm. Such economies result from the "scope" of the firm's operations and can only be achieved in the case of a joint production process.

Carriers who offer both scheduled and charter services can achieve a better utilization of their equipment when the peak in these two services differs and when the equipment can be transferred from one service to the other. The productivity results observed for Quebecair and Nordair might be explained by the existence of such cost complementarities but their performance might also be overestimated due to the fact that the physical measure of charter output used here is miles flown. The patronage of charter services has a tendency to vary significantly from one year to another. Therefore, fluctuations in the charter output are far from being monotonic. But the Divisia approach under such a scenario can present a distorted picture of carriers' performance. For instance, Quebecair saw its charter miles grow by 32% between 1980 and 1981, due to an increase in the charter services to the United States. Under the CRO Divisia index, i.e., after weighting that growth by the average revenue share of charter services for those two years, charter services growth was still 15%. Therefore, for a year which represents the beginning of a recession, Quebecair's CRO index shows for 1981 an increase over the previous year which was

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* Roger Roy, Economies of Scale in the Airline Industry, Canadian Transport Commission, Research Branch, Research Report No. 10-80-06E, June 1980.

Table 3.2

ANNUAL PERCENTAGE RATES OF GROWTH OF FACTOR PRODUCTIVITY
Regional Carriers

	PWA		Nordair	
Period	CRO/TFI 1	CRO/TFI 2	CRO/TFI 1	CRO/TFI 2
1960-1976	4.1	1.7	0.8	0.9
1960-1968	2.5	-0.8	-0.6	-2.2
1968-1976	5.6	4.3	2.3	1.5
1960-1981	3.3	1.6	1.4	0.6
1970-1981	2.2	2.1	0.5	-0.2
1968-1981	3.7	3.0	2.7	2.3
1977-1981	-0.9	-0.2	2.3	2.8

	Quebecair		EPA	
Period	CRO/TFI 1	CRO/TFI 2	CRO/TFI 1	CRO/TFI 2
1960-1976	3.4	-0.3	2.3	2.1
1960-1968	1.8	2.0	-2.2	-2.2
1968-1976	5.0	2.3	7.0	4.6
1960-1981	3.3	2.4	1.7	0.8
1970-1981	3.2	1.8	2.0	0.8
1968-1981	4.3	2.7	4.2	2.7
1977-1981	2.0	2.4	-1.7	-1.8

somewhat distorted by that increased importance of charter services in Quebecair operations.

Two weak points of the Divisia approach as defined and measured in this study have been disclosed. The first one has to do with the physical unit of measurement for charter operations. Miles flown was the only physical unit that was reported by carriers as far back as 1960 for charter services. However, it represents only a proxy for the actual output generated by charter operations.

One has to verify whether the measurement unit used for charter services (miles flown) results in a distortion of the productivity results. Keeping for other outputs and inputs the measures defined previously, three physical measurement units for charter services were used over the 1970 to 1981 period: miles flown, passenger-miles and total tonne-miles. Table 3.3 below allows the test of the sensitivity of TFP measures to the charter service measurement unit.

Table 3.3

ANNUAL GROWTH RATE OF TOTAL FACTOR PRODUCTIVITY
UNDER DIFFERENT MEASURES OF CHARTER'S OUTPUT,
1970-1981
(%)

Measurement Unit of Charter Services	Air Canada	CP Air	PWA	Nordair	Quebecair	EPA
Miles Flown	2.4	3.5	1.7	3.7	0.8	0.4
Passenger-Miles	2.5	3.7	1.4	6.9	1.1	1.9
Tonne-Miles	2.6	3.7	1.8	6.0	0.6	1.9

Charter services are more important for regional carriers and the table above illustrates this to some extent. Therefore, it is not surprising to find that regional carrier productivity performance is more sensitive to the measure of charter operations, Nordair being the carrier with the most sensitive performance to the actual charter service measure used.

The other weakness is a weakness only because of the trend taken by some key parameters entering into the TFP calculations. The relative instability of growth patterns observed between 1960 and 1981 in the Canadian air transport industry should prevent analysts from making statements based on the derived productivity measures which could turn out to be biased because of the irregularities in the trend of the air activities. This problem is more important for a carrier like

Quebecair while major airlines, with a more stable pattern of growth over the 1960 to 1981 period, are not affected by it.

3.2 Sources of Output Growth

The previous section described the average productivity growth experienced by Canadian air carriers as being rapid at one stage or another between 1960 and 1981, with recent evidence indicating a substantial erosion of productivity gains. The average growth of total factor productivity was shown for several sub-periods. After 1977, a levelling-off in the growth rate of productivity occurred. It is important to understand the role of total factor productivity in accounting for the development of output. The objective of this section is to separate the part of output growth due to variations in the quantities of factor inputs* from that due to other changes such as in the quality of inputs as well as others. Variations in factor inputs affect employment, fleet (through acquisition and/or deletion), fuel consumption and other materials. If quantitative changes in input utilization will impact on productivity performance, qualitative changes will also have their importance in total factor productivity. Output can also vary because of economies of scale, economies of scope and various network changes affecting an airline's route structure.

Due to data limitations, the contribution of these various sources of output growth cannot all be measured. It was possible to isolate only some of the sources of output growth, and variations in airline output were associated with changes in input quantities. The residual, i.e., output variations not explained by quantitative changes in inputs, is explained by quality changes as well as by other changes. With respect to that residual growth in output, the introduction of jet equipment resulted in major improvements in aircraft productivity. Therefore, jet aircraft represent a quality improvement over the aircraft they replaced and an attempt was made to measure the effects of such a qualitative change. Therefore, three causes for output change have been differentiated here. The first one attributes a portion of output changes to changes in input quantities. The second one has to do with aircraft improvements. Finally, the change in output not explained by the first two components is imputed to all other factors that can impact on output. Table 3.4 presents the contributions of each of these three components to the growth of output for the period 1960 to 1981 while Table 3.5 gives the same information for the years 1977 to 1981. Tables A.10.1 to A.10.4 in Appendix A present the same information but at a refined level of detail. Tables A.10.5 to A.10.11 in the same appendix present a detailed picture of the sources of growth in the average annual percentage rate of increase in output for other sub-periods of interest within the years 1960 and 1981. These two periods are presented in order to illustrate why the performance of Canadian air carriers has deteriorated in recent years.

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* For the separation of the part of output growth due to variations in the quantities of factor inputs, the quantitative unit used to measure the capital input has been the number of aircraft. On the other hand, the Total Factor Input Index used either aircraft hours flown or aircraft ton-hours for its measure of capital. Therefore, the percentage changes in input quantities are not comparable with the Total Factor Input Index used in the TFP measure.

When looking at the whole period, 1960 to 1981, it is possible to notice differences among carriers concerning the sources of their output growth. The discussion that follows is based on Table 3.4. First, changes in output growth attributable to "other factors" were relatively more important for Air Canada and CP Air. For the regional carriers, between 68% and 80% of their output growth was explained by changes in input quantities. If one adds the changes in output associated with the utilization and quality of aircraft, then 75 to 91% of output growth is explained. Therefore, for the regional carriers, the Divisia approach allows us to characterize most of the output growth.

Moving to the more recent experience, Table 3.5 indicates that Air Canada and CP Air output has been growing at a much slower rate in recent years. Most of that growth is explainable in the case of Air Canada by the increase in the quantities of input used. Meanwhile, CP Air's performance is somewhat different. CP Air as well as PWA and EPA were increasing the quantities of inputs used in their production process at a faster rate than the rate of growth of the demand for their services. The most important point to notice with respect to the performance achieved by Canadian air carriers between 1977 and 1981 has to do with the exhaustion in recent years of the possibility to improve productivity performance through acquisition of new aircraft. Table 3.5 shows in these years a negative rate of changes in aircraft utilization and quality for all carriers except EPA. Due to a slowdown in output growth, carriers have had to adjust their operations to reflect the demand for their services. These adjustments have meant changes in aircraft utilization. In the case of CP Air and Quebecair, these adjustments appear to have been important. Quebecair's performance is interesting. If its output decreased between 1977 and 1981, quantities of inputs used also decreased. But in the case of inputs, the rate of diminution was less important than the one experienced in output. It seems to have been a managerial decision to adjust to the new output scenario mostly through adjustments in the utilization of aircraft.

PWA and EPA are the only two carriers with a negative contribution of the factors such as economies of scale, economies of scope and changes in route structure, to the rate of increase in their output. Curiously, PWA merges its operations with

Transair at the end of 1979 while EPA underwent corporate changes which have resulted in a greater diversification of activities, air services being simply one of them.

In the case of Air Canada, the decision to change the capital structure of the carriers appears to have had a negative impact since such an impact would become part of the contribution of other factors to output growth, a contribution which has been negligible between 1977 and 1981. Irrespective of the last statement, the validity of that decision cannot be questioned on the basis of the results of a productivity study. Even though the financial viability of a carrier and the level of its productivity performance are closely linked to each other, it is difficult to establish the kind of relationship that exists between the two concepts since other factors which affect both can have, for a given year, differing influences on each of them.

Table 3.4

SOURCES OF GROWTH IN AVERAGE ANNUAL PERCENTAGE RATE OF INCREASE IN OUTPUT 1960-1981

	Air Canada	CP Air	PWA	Nordair	Quebecair	EPA
Output (CRO) Growth	9.1	12.8	10.3	10.3	10.3	9.9
Changes in Input Quantities	5.1 (56%)	8.5 (66%)	8.9 (69%)	8.2 (80%)	7.0 (68%)	7.9 (79%)
Changes in Aircraft Utilization and Quality	1.0 (11%)	-0.7 (-6%)	2.1 (17%)	1.6 (15%)	0.8 (7%)	1.2 (12%)
Changes Attribuable to Other Factors	3.0 (33%)	5.0 (40%)	1.8 (14%)	0.5 (5%)	2.5 (25%)	0.8 (9%)

Table 3.5

SOURCES OF GROWTH IN AVERAGE ANNUAL PERCENTAGE RATE OF INCREASE IN OUTPUT 1977-1981

	Air Canada	CP Air	PWA	Nordair	Quebecair	EPA
Output (CRO) Growth	5.5	8.3	12.4	10.9	-4.7	9.2
Changes in Input Quantities	5.4	14.7	13.7	9.0	-0.5	10.9
Changes in Aircraft Utilization and Quality	-0.2	-8.2	-0.4	-0.9	-6.5	0.1
Changes Attribuable to Other Factors	0.3	1.8	-0.9	2.8	2.3	-1.8

Chapter 4

TOTAL FACTOR PRODUCTIVITY: TRANSLOG MULTILATERAL PRODUCTIVITY INDEX APPROACH

The definitions of productivity vary and the magnitude of productivity growth can be compared from one study to another only after a careful investigation of both the definition of productivity and the measures of the variables used. This chapter concentrates on an area which is of interest in empirical investigations of productivity: inter-firm comparisons of productivity. Recently multilateral indexes have been proposed for productivity comparison. Appendix E defines the approach and this chapter provides estimates of the "relative" levels of total factor productivity for Canadian air carriers during the period 1960-1981. Multilateral indexes use revenue shares as weights in the construction of the output index entering in the TFP index calculations. Such weights imply that the production structure of Canadian airlines exhibits constant returns to scale and that the output prices are proportional to their marginal costs. Such assumptions were said to be reasonable in the context of the Canadian air transport industry. The chapter ends with a section dealing with a confrontation of TFP estimates with operating characteristics of the individual carriers to determine which proportion of the average annual productivity growth is explained by these characteristics. The data actually used under this approach are described in Section 2.2.

4.1 Productivity

Appendix E defines from a methodological point of view the index used to compute TFP indexes for the seven Canadian air carriers. The indexes are presented in Table 4.1. Tables 4.1 to 4.3 indicate growth rates for Canadian carriers, TFP, input and output indexes for a wide range of periods between the years 1960 to 1981. The translog multilateral productivity index approach permits the comparison of two carriers' productivity. This comparison is possible because the productivity of two carriers is defined relative to the productivity of all carriers in the Canadian air transport industry. The industry productivity is measured as the geometric mean of the bilateral productivity comparisons between a given carrier and each of the other carriers in the industry.

The translog multilateral productivity index is the difference between the translog multilateral output and input indexes. Under this approach, one can examine in relative terms the levels of performance achieved. On the output side, the output measure used for charter services gives too much weight to

Table 4.1

TRANSLOG MULTILATERAL PRODUCTIVITY INDEXES
AVERAGE ANNUAL GROWTH RATES
Total Factor Productivity
(%)

	Total Factor Productivity						
Period	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960-1970	5.1	3.6	-2.8	-3.0	-1.1	1.7	-3.3
1970-1981	-1.2	0.7	-1.1	0.6	-0.7	1.3	-3.8
1960-1981	1.8	2.1	-1.9	-1.1	-0.9	1.5	-3.6
1960-1967	6.0	3.4	-2.2	-6.5	-1.7	1.6	-2.6
1967-1981	-0.3	1.4	-1.8	1.6	-0.5	1.4	-4.0
1960-1976	1.5	2.2	-2.2	-2.4	-0.4	0.9	-3.3
1976-1981	2.7	1.5	-0.9	3.0	-2.5	3.4	-4.3
1970-1975	-4.6	-1.0	-1.1	-3.2	0.7	0.8	-2.4
1975-1981	1.6	2.1	-1.0	3.7	-1.8	1.6	-4.9
1978-1981	-2.2	-0.9	-5.1	0.8	3.7	0.7	-12.6

Table 4.2

TRANSLOG MULTILATERAL PRODUCTIVITY INDEXES
AVERAGE ANNUAL GROWTH RATES
Inputs
(%)

Period	Inputs						
	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960-1970	-1.1	0.6	3.0	4.4	-3.1	-3.8	0.0
1970-1981	-5.7	-4.3	-0.5	10.1	2.8	0.4	0.1
1960-1981	-3.5	-2.0	1.2	7.3	0.0	-1.6	0.1
1960-1967	1.4	2.1	-1.8	7.2	-4.5	-4.6	0.1
1967-1981	-6.0	-4.0	2.7	7.4	2.3	-0.1	0.1
1960-1976	-3.0	-1.3	0.5	2.9	0.6	0.6	-0.4
1976-1981	-5.0	-4.2	3.3	21.4	-2.0	-8.7	-1.6
1970-1975	-7.5	-4.8	-2.6	-1.1	6.4	10.3	-0.8
1975-1981	-4.2	-4.0	1.3	19.4	-0.2	-7.8	0.9
1978-1981	-6.8	-4.8	5.3	37.6	-1.2	-21.8	2.4

Table 4.3

TRANSLOG MULTILATERAL PRODUCTIVITY INDEXES
AVERAGE ANNUAL GROWTH RATES
Outputs
(%)

Period	Outputs						
	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960-1970	4.0	4.2	0.2	1.4	-4.2	-2.1	-3.3
1970-1981	-6.9	-3.6	-1.5	10.6	2.1	1.7	-3.7
1960-1981	-1.7	0.1	-0.7	6.2	-0.9	-0.1	-3.5
1960-1967	7.4	5.5	-3.9	0.7	-6.2	-3.0	-2.5
1967-1981	-6.3	-2.6	0.9	9.0	1.8	1.3	-4.0
1960-1976	-1.5	0.9	-1.7	0.5	0.3	1.5	-3.7
1976-1981	-2.3	-2.7	2.4	24.5	-4.5	-5.3	-2.7
1970-1975	-12.1	-5.8	-3.7	-4.3	7.1	11.2	-3.2
1975-1981	-2.6	-1.8	0.3	23.1	-2.0	-6.3	-4.1
1978-1981	-8.9	-5.7	0.1	38.4	2.6	-21.1	-10.2

charter service in the measure of output when charter services represent an important source of a carrier's revenues. That problem was also present under the Divisia approach. Irrespective of that problem, the computed indexes yield various observations on the relative performance of Canadian air carriers.

In recent years (since 1967), Air Canada's contribution to the industry output growth has eroded. The industry growth has emanated mostly from CP Air and the regional carriers. The two carriers who have experienced, in relative terms, the most significant growth in their translog multilateral output index between 1967 and 1981 are Nordair and Quebecair. Pointedly, these two carriers have relatively important charter services in their operations.

In order to show a sustained growth in productivity over a given period of time, a carrier has to achieve a higher growth in its output than in its input. This explains why CP Air and Air Canada and Quebecair show relatively good performance in most of the periods investigated with this approach.

Section 3.2 of this text mentioned that the rate of diminution of inputs in Quebecair was not enough to compensate for the decrease in output. When the same situation is measured in relative terms, not only was the relative drop in Quebecair input utilization the most important of the industry but it was more than sufficient to account for the relative decrease in output. Therefore, under the multilateral index approach, Quebecair stands out as one of the productive Canadian air carriers. CP Air and Air Canada are two other carriers which, over the years, have achieved high levels of productivity both in relative and in absolute terms. They have related their input growth to their output growth in order to achieve efficient utilization of their inputs in their production process. EPA stands out as being unable to achieve relatively high levels of productivity. According to the multilateral methodology, EPA's performance is explained by the fact that the relative average rate of adjustment in its input utilization was always below the industry performance. In the case of PWA and Nordair, their relative performance was found to be always below industry productivity achievement.

The translog multilateral estimates of TFP can be compared with the Divisia estimates, a more traditional indicator of airline productivity. However, the reader has to be warned that identical changes are captured under the Divisia approach in absolute terms while under the multilateral approach they would be identified in relative terms. Such a difference in the definition of productivity cannot be neglected. Table 4.4 presents these indexes for the period 1960-1981 in both cases ranking the performance achieved by each carrier. The ranking illustrates some similarities, but major differences are also

Table 4.4

INTER-APPROACH COMPARISON OF PRODUCTIVITY GROWTH OVER THE PERIOD 1960 TO 1981

	Outputs		Inputs		TFP	
Carrier	**Divisia**	**Multilateral**	**Divisia**	**Multilateral**	**Divisia**	**Multilateral**
Air Canada	9.1(6)	1.7(1)	6.0(6)	-3.5(6)	2.9(2)	1.8(2)
CP Air	12.8(1)	0.1(2)	7.6(4)	-2.0(5)	4.8(1)	2.1(1)
PWA	12.8(1)	-0.7(4)	11.0(1)	1.2(1)	1.6(4)	-1.9(5)
Nordair	10.2(4)	-0.9(5)	9.6(2)	0.0(3)	0.6(6)	-0.9(4)
Quebecair	10.3(3)	-0.1(3)	7.6(4)	-1.6(4)	2.4(3)	1.5(3)
EPA	9.9(5)	-3.5(6)	9.0(3)	0.1(2)	0.8(5)	-3.6(6)

Note: Carrier's rank under each approach is in brackets.

evidenced. Under both approaches, Air Canada, CP Air and Quebecair are the carriers with the highest average levels of productivity. In contrast, TFP estimates under the Divisia approach show for PWA, Nordair and EPA, positive levels of productivity while under the translog multilateral approach their performance is negative. The figures presented thus far indicate also that recently carriers have had difficulties in maintaining high levels of productivity.

The same seven major carriers are included in the definition of the Canadian air transport industry, but these carriers are far from being homogeneous. They differ among other things according to their size, their network, and to some extent in the type of equipment used. Since the multilateral approach treats all carriers and time periods symmetrically, it was believed that using various definitions of the industry would be one way of testing the desirability of the symmetry of treatment assumption. These definitions, which were differentiated only on the basis of the number of carriers included in the industry, form the basis here to test empirically whether or not the performance of Canadian air carriers, as measured by the multilateral TFP index, differed according to the similarities or the dissimilarities of the carriers included in the industry definition. Various definitions of the industry were used. The first one included all seven carriers. The second one incorporated Air Canada, CP Air and PWA. The third one defined the industry in terms of Transair, Nordair, Quebecair and EPA. The last one regrouped the five regional carriers, PWA, Transair, Nordair, Quebecair and EPA. Without going into the details of the results obtained, it is important to summarize the empirical evidence. The multilateral index approach turned out to be sensitive to the definition of the industry used to make the comparisons. From such a finding, which cannot be alluded, it can be conjectured that use of the translog index is preferable when the comparisons are to be done between relatively similar carriers. The results presented in this section included all seven carriers. Since the multilateral TFP index measurements have indicated that the productivity growth varied by carriers, the next question to address is how much of the said differential can be attributed to the specific characteristics of each carrier's operations.

4.2 Covariance Analysis

This section proposes to identify the sources of variation in the productivity of Canadian air carriers. These sources are generally classified into two groups: the first comprising such quantifiable characteristics of production operations as output level, load factor, average distances covered and enterprise capacity, the second group comprising all of the residual or unexplained variations which can be related to regulatory, managerial or other changes. It should be pointed out that covariance analysis does not pursue the same aim as the analysis presented in Section 3.2. The analysis in the preceding chapter was geared to break down output growth into its different sources of change. The aim here is to explain the sources of productivity variation.

An analysis of covariance is used here to establish the quantitative significance of these two types of productivity. In this context, total factor productivity becomes the endogenous variable, i.e., the variable to be explained. Caves, Christensen and Tretheway (1981) also sought to explain the causes of U.S. trunk and local service airline productivity growth by means of covariance analysis. In their opinion, the explanatory variables represent the contribution of the quantifiable operating characteristics and the binary variables represent the residual variations in productivity or the unquantifiable sources of productivity.

Then, the coefficients estimated by means of covariance analysis allow us to decompose productivity variations into the output and different inputs and to calculate the residual variations.

The explanatory variables retained a priori for this covariance analysis are the translog multilateral index of output (OUT), the average stage length (ASL), the number of aircraft ton-miles performed (ATH) and the load factor (LF). The last three variables were standardized with respect to the industry average.

The heterogeneity between carriers in Canada is such that it has been judged important to use more than one definition of the air transport industry. By definition of the industry one should understand the number of carriers put together to make what is called an industry.

A first way to define the industry consists in incorporating Air Canada, CP Air and PWA -- industry A -- and Transair, Nordair, Quebecair and EPA -- industry B. The variables for each carrier are then calculated relative to the average of the industry group (A or B) in which it is classified.

A second way to define the industry consists of grouping together all the regional airlines, i.e., PWA, Transair, Nordair, Quebecair and EPA.

A third and final way to calculate the indices is relative to the industry incorporating all seven carriers.

Capital entering into the composition of the productivity index was measured in three ways, as was explained in Section 2.2.5. These three measures of capital gave rise to three productivity indices, the first relating to the number of aircraft (TFP 1), the second to the number of aircraft hours (TFP 2) and the third to aircraft ton-hours performed (TFP 3).

Econometricians agree that it is important to take into account both the years and the groups when working with grouped data repeated over time. These characteristic effects of the years and/or the groups, which cannot be accounted for by ASL, ATH, OUT or LF, can be obtained by binaries associated with the firms or the years.

The models applying to the type of sample used here, an instantaneous cross-section over 22 years, are called analyses of covariance. Before proceeding any further, it is important to give a brief description of what covariance analysis entails. A covariance analysis is a multiple regression to which group and/or time-specific variables (binaries) are added. In the present case, the binaries are the airlines. The purpose is to secure information that might otherwise be lost owing to the fact that the seven chronological series — seven carriers — are aligned end to end to form a single vector.

This vector comprises a total of 152 observations, i.e., seven airlines multiplied by 22 years, or 20 years for Transair given its merger with PWA in late 1979.

Once the variables of the covariance analysis have been established, it remains to find the optimum specification of the equation. Based in part on the study by Caves, Christensen and Tretheway (1981), two formulae were estimated, i.e., log-linear and rate of growth (i.e., in log differential). Owing to problems of auto-correlation of random errors over time, only the first-differential formula was retained.

Simple regressions were made to ascertain the correlation between productivity and the explanatory variables taken one at a time. Table 4.5 gives these results.

When the other explanatory variables are added to the regressions, the R^2's are much higher and the coefficients almost always significant for OUT, ASL and ATH. The significant coefficients are always on the same order of magnitude, between 0.90 and 1.05 for OUT, about 0.18 for ASL and -0.75 for ATH. Table 4.6 gives the results of the multiple regressions based on different industry definitions.

The capacity of output to explain productivity is highly important. It is the most statistically significant explanatory variable in all regressions. An increase in output should, a priori, have a positive effect on productivity.

Table 4.5

UNIVARIATE REGRESSIONS, 1960-1981

7 carriers

	D ln TFP 3	D ln TFP 3	D ln TFP 3
OUT	0.4300*		
ASL		-0.1300	
ATH			-0.120
cst	0.0006	-0.0040	-0.005
R^2	0.3000	0.0009	0.030
D.W.	1.8200	2.1300	2.110

5 carriers

	D ln TFP 2	D ln TFP 2	D ln TFP 2	D ln TFP 3	D ln TFP 3	D ln TFP 3
OUT	0.5800*			0.5500*		
ASL		-0.04000			-0.170	
ATH			-0.230*			-0.280*
cst	-0.0004	-0.00400	-0.006	-0.0005	-0.004	-0.006
R^2	0.3600	0.00068	0.060	0.3300	0.012	0.090
D.W.	1.4500	1.82000	2.030	1.4500	1.410	2.000

	4 carriers			3 carriers		
	D ln TFP 3	D ln TFP 3	D ln TFP 3	D ln TFP 3	D ln TFP 3	D ln TFP 3
OUT	0.360*			0.480*		
ASL		-0.770			0.430*	
ATH			-0.060			-0.0080
cst	-0.001	-0.003	-0.004	-0.002	-0.002	-0.0020
R^2	0.270	0.004	0.006	0.440	0.080	0.0001
D.W.	2.040	2.510	2.520	1.740	1.820	1.8600

* Significant at $\alpha = 0.05$.

Table 4.6

MULTIPLE REGRESSIONS, 1960-1981

7 carriers

	D ln TFP 3	D ln TFP 2
OUT	0.9300*	0.9500*
ASL	0.0500	0.1500*
ATH	-0.7700*	-0.7500*
cst	-0.0017	-0.0015
R^2	0.7900	0.7700
D.W.	2.2800	2.1900

5 carriers

	D ln TFP 2	D ln TFP 3
OUT	1.0000*	0.9900*
ASL	0.1800*	0.0600
ATH	-0.7900*	-0.8100*
cst	-0.0030	-0.0030
R^2	0.8300	0.8400
D.W.	2.2400	2.4000

4 carriers (Transair, Nordair, Quebecair and EPA)

	D ln TFP 2	D ln TFP 3
OUT	0.8800*	0.8800*
ASL	0.1400	0.0200
ATH	-0.7000*	-0.7200*
cst	-0.0020	-0.0020
R^2	0.6900	0.7400
D.W.	2.3400	2.4800

3 carriers (Air Canada, CP Air and PWA)

	D ln TFP 2	D ln TFP 3
OUT	0.9800*	0.8600*
ASL	0.1200	-0.1000
ATH	-0.7100*	-0.6200*
cst	0.0100	-0.0200
R^2	0.4500	0.7700
D.W.	1.2000	1.8400

* Significant at $\alpha = 0.05$.

The presence of economies of scale, however minimal, is one factor explaining this relationship. Output must obviously be closely linked with productivity, by the very definition of productivity. Growth in output for the same quantity of input may stem from technological advancement of efficient substitution among inputs, the two then being capable of producing productivity growth. The value of the output coefficient is very stable in both the multiple regressions and the covariance analyses, regardless of the industry's definition used to construct the indices.

Table 4.7 summarizes the results of the analysis of covariance. It can be compared with Table 4.6 to verify the similarity of the coefficients estimated under various combinations of firms comprising the base industry and various explanatory variables.

The ASL variable poses a different problem. The anticipated effect of an increase in average stage length is some increase in productivity. However, the level of ASL differs substantially among the different carriers, particularly between the two majors and the regionals. For instance, the removal of Nordair significantly augments the ASL average. Furthermore, there is a fairly strong correlation between ASL and ATH and between OUT and ATH. Given that average stage length varies more with the carriers than with the years, the variability of the coefficients can be explained by the industry definition used to compute the indices. It is noteworthy that the results are more satisfactory with the industry definition incorporating all seven airlines or the five regional airlines than with the definition comprising three and four airlines.

Any increase in average stage length (ASL) should entail some productivity improvement. Prior studies have shown, moreover, that average cost drops as average stage length rises. Douglas and Miller (1974), for example, found a significant positive relationship between operating cost per available ton-mile and the ASL logarithm. Caves, Christensen and Tretheway (1981), however, were unable to establish any relationship between the ASL growth rate and the productivity growth rate, whether through their multiple regression or covariance analysis. Nor could they establish any significant relationship between the levels of the two variables in their covariance analysis using different explanatory variables. In their opinion, the lack of any significant relationship is attributable to the presence of binary variables characterizing the firms, the models without firm-specific binaries presenting a significant ASL coefficient.

The results in Table 4.7 run counter to the explanations of Caves, Christensen and Tretheway (1981). Whereas those authors attribute the non-significativeness of the ASL variable to the presence of firm-specific binaries, the equations presented in Table 4.7 give significant ASL coefficients in spite

Table 4.7

COVARIANCE ANALYSES, 1960-1981

	7 carriers	5 carriers[1]	4 carriers[2]	3 carriers[3]
	D ln TFP 2	D ln TFP 2	D ln TFP 3	D ln TFP 3
OUT	0.950*	1.010*	0.880*	0.830*
ASL	0.160*	0.180*	0.020	-0.080
ATH	-0.750*	-0.800*	-0.730*	-0.580*
F1	0.017	N/A	N/A	0.009
F2	0.016	N/A	N/A	0.005
F3	-0.004	0.008	N/A	-0.020*
F4	-0.018	-0.020	-0.090	N/A
F5	0.013	0.020*	0.020	N/A
F6	-0.020	-0.005	-0.010	N/A
F7	-0.016	-0.020	-0.009	N/A
R^2	0.780	0.850	0.760	0.800
D.W.	2.390	2.370	2.690	2.160
SCC	0.060	0.060	N/A	N/A

* Significant at $\alpha = 0.05$.

Note: The binary variables of time did not prove statistically significant. Their presence augments the R^2 only because the addition of variable (21), even insignificant, augments the R^2. Those models were therefore not retained.

[1] PWA, Transair, Nordair, Quebecair and EPA.
[2] Transair, Nordair, Quebecair and EPA.
[3] Air Canada, CP Air and PWA.

of the presence of such binaries. The deviation in these sets of results may stem from the fact that the operating characteristics of the Canadian air carrier differ from those observed for U.S. carriers.

The ATH variable is the most robust in the different covariance analyses, under either TFP 2 or TFP 3.* Its coefficient always ranges between -0.70 and -0.80, depending on the industry definition used to compute the indices. The anticipated effect of ATH on productivity is positive. However, the utilization of larger aircraft may also translate into declines in productivity if the aircraft used cannot efficiently satisfy their intended market. Such cases are seen when carriers enhance their productivity by grounding part of their fleet. The regional airlines, mainly because of the length of their routes, are most likely to find themselves with aircraft of non-optimal size.

The load factor (LF) defined as the ratio of revenue passenger-miles to number of seat-miles is an explanatory variable that was rejected for the models presented in Tables 4.5 to 4.7. The LF variable plays an important role in the financial performance of an airline. Any rise in the load factor should translate into productivity improvement. Revenue will be insufficient to cover costs if the actual load factor is far below the load factor anticipated when calculating fares.

If an aircraft has to fly at 40% capacity and a 60% load factor was expected, the airline must use the same amount of fuel and meet the same personnel expenditures. In sum, it incurs the same fixed costs for the small savings that it may be able to score, on passenger meals for instance. The announcement of reduced fares is another case to consider. These fares may be offered at lower than the marginal cost with an eye to improving the load factor. However, the LF variable, as used here, i.e., according to the possibilities allowed by available data, is subject to caution. Indeed, the load factor considered reckons only with unit-toll services; charter and specialty flying are altogether excluded from its calculation. The LF variable also has the disadvantage of forcing Nordair out of the sample when this explanatory variable is introduced in the model, as this item was not available for the carrier at the beginning of the study period. Actually, the LF variable did not prove to contribute an adequate additional explanation to the model.

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* A variable is robust when its coefficient successfully passes a given test, the Student test in the case at hand. In the present context, the variable is significant regardless of the specification of the model estimated with either TFP 2 or TFP 3, time- or firm-specific binaries or their combinations.

Statistically speaking, the best model calculated under each of the industry definitions was chosen to calculate the unexplained productivity growth rates by explanatory variables or binaries. Tables 4.8 to 4.11 summarize these results, which were obtained by weighting each of the explanatory factors as well as total factor productivity by their respective shares in the total expenditures of the industry in which each carrier was incorporated. These weighted shares were then multiplied by their covariance analysis coefficient. The unexplained variations in productivity as presented in Tables 4.8 to 4.11 are thus variations unexplained by the models of covariance in Tables 4.5 to 4.7. Take, for example, the 1960-1961 productivity variation for the industry incorporating all seven airlines. The observed growth rate was 4.13%. The model of covariance explained 1.05% of the growth, with 0.59% attributed to output, 0.38% to ASL and 0.08% to ATH. For that year, the unexplained productivity growth rates thus stands at 3.08%.

On the average, a fairly small proportion of TFP variation, 0.81% to be precise, remains unexplained for the seven carriers for the period 1970-1981. For the period 1960-1970 a somewhat higher proportion remains unexplained, 2.36%, or about half of the productivity variation for that period. For certain years, such as 1964-1965 and 1977-1978, the unexplained share of total factor productivity is as low as 0.09 or -0.05. Other years, such as 1975 to 1977, seem totally unexplained for the industry definition incorporating the five regional airlines.

The table below summarizes the most interesting results from Tables 4.8 and 4.11.

	Years with a large proportion of unexplained productivity	Years with a small proportion of unexplained productivity
Table 4.8 7 carriers	67-68 and 79-80	72-73 and 77-78
Table 4.9 5 carriers	75-76 and 76-77	61-62 and 68-69
Table 4.10 4 carriers	70-71 and 79-80	60-61 and 63-64
Table 4.11 3 carriers	68-69 and 77-78	60-61 and 62-63

It is readily observed that virtually no one year is common to several carrier groups.

The substantial dissimilarity in the results given in the different tables shows that the method is highly sensitive to the composition of the industry and may not be ideal in the case of a heterogeneous industry such as the Canadian airline industry.*

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* For a more detailed explanation of the results, see Appendix F.

Table 4.8

DECOMPOSITION OF GROWTH RATE OF WEIGHTED TFP
Seven Carriers
(%)

Years	Output	ASL	ATH	TFP	Unexplained	Unexplained TFP/ TFP
60-61	0.59	0.380	0.08	4.13	3.08	0.75
61-62	15.70	0.480	-5.11	10.08	-0.99	-0.10
62-63	16.44	0.410	-3.75	22.49	9.39	0.42
63-64	-8.20	-0.800	4.98	-6.27	-2.25	0.36
64-65	10.18	-0.130	-2.18	8.62	0.75	0.09
65-66	-0.40	0.370	-1.04	-2.39	-1.32	0.55
66-67	12.03	0.350	-10.48	2.21	0.31	0.14
67-68	-2.93	-0.210	0.90	0.60	2.84	4.73
68-69	-21.69	-0.850	17.03	3.13	8.64	2.76
69-70	5.72	-0.270	-5.11	3.42	3.08	0.90
70-71	-13.49	-0.060	7.51	-3.71	2.33	-0.63
71-72	2.02	-0.680	2.46	4.40	0.60	0.14
72-73	-10.38	-0.110	4.74	-5.84	-0.09	0.01
73-74	-13.18	-0.630	7.25	-4.20	2.36	-0.56
74-75	-23.30	0.008	9.20	-12.11	1.98	-0.16
75-76	-2.01	-0.120	1.46	-1.46	-0.79	0.54
76-77	-4.74	-0.380	4.15	1.30	2.27	1.75
77-78	13.09	0.290	0.93	13.68	-0.63	-0.05
78-79	5.58	0.550	-4.99	1.79	0.65	0.36
79-80	-12.38	0.800	8.88	-0.61	2.09	-3.43
80-81	-10.99	-0.900	3.15	-10.55	-1.81	0.17
60-70	2.74	-0.030	-0.47	4.60	2.36	0.51
70-81	-6.34	-0.110	4.07	-1.57	0.81	-0.52

Table 4.9

DECOMPOSITION OF GROWTH RATE OF WEIGHTED TFP
Five Regionals Carriers
(%)

Years	Output	ASL	ATH	TFP	Unexplained	Unexplained TFP/ TFP
60-61	-4.13	-0.350	9.480	11.44	6.44	0.56
61-62	-5.85	-0.130	2.620	-3.60	-0.24	0.07
62-63	-4.20	-0.380	-1.490	-7.10	-1.03	0.14
63-64	6.19	-0.340	-4.630	2.66	1.44	0.54
64-65	3.47	0.170	-2.700	3.57	2.63	0.74
65-66	-3.83	0.470	3.510	0.90	0.75	0.83
66-67	2.95	0.050	-3.160	0.40	0.56	1.40
67-68	2.54	0.410	-2.040	-1.64	-2.55	1.55
68-69	9.08	0.800	-11.400	-1.62	-0.10	0.06
69-70	5.44	-0.002	-4.610	-2.33	-3.16	1.36
70-71	-6.02	-1.100	4.220	-2.48	0.42	-0.17
71-72	3.03	-0.007	-1.880	-2.28	-3.43	1.50
72-73	-3.03	0.050	0.007	-5.27	-2.29	0.43
73-74	-4.33	-0.450	4.590	-5.49	-5.30	0.97
74-75	-0.28	-0.440	4.240	-1.31	-4.83	3.69
75-76	-4.65	0.080	4.960	-0.01	-0.40	40.00
76-77	2.79	-0.200	-5.030	-0.04	2.40	-60.00
77-78	-2.07	-0.220	1.550	-1.01	-0.27	0.27
78-79	4.25	0.460	-1.050	-0.58	-4.24	7.31
79-80	7.26	1.070	-5.460	0.52	-2.35	-4.52
80-81	-0.02	-0.530	-0.940	-10.18	-8.69	0.85
60-70	1.17	0.070	-1.440	0.12	0.32	2.67
70-81	-0.49	-0.050	0.330	-0.83	-0.62	0.75

Table 4.10

DECOMPOSITION OF GROWTH RATE OF WEIGHTED TFP
Transair, Nordair, Quebecair and EPA
(%)

Years	Output	ASL	ATH	TFP	Unexplained	Unexplained TFP/ TFP
60-61	3.39	0.050	0.26	3.47	-0.23	-0.07
61-62	-4.30	0.000	1.60	0.42	3.12	7.43
62-63	0.54	0.090	-1.28	-3.47	-2.82	0.81
63-64	1.50	0.010	0.65	2.11	-0.05	-0.02
64-65	-1.90	-0.030	0.68	-0.49	0.76	-1.55
65-66	-1.81	0.020	2.09	-0.54	-0.84	1.56
66-67	-0.07	0.050	0.38	-1.08	-1.44	1.33
67-68	0.27	0.020	0.22	0.61	0.10	0.16
68-69	-0.88	-0.020	-0.78	-1.07	0.61	-0.57
69-70	2.14	-0.050	-0.71	1.83	0.45	0.25
70-71	-0.43	-0.030	-0.03	0.04	0.53	13.25
71-72	2.49	-0.040	-1.99	0.41	-0.05	-0.12
72-73	-2.26	-0.003	-0.22	-2.74	-0.26	0.09
73-74	-1.66	0.020	1.14	-1.09	-0.59	0.54
74-75	-2.35	0.080	-0.51	2.94	1.02	0.35
75-76	-0.87	-0.040	0.69	-0.30	-0.08	0.27
76-77	1.60	0.040	-2.76	-0.41	0.71	-1.73
77-78	-0.35	0.020	-0.07	-0.60	-0.20	0.33
78-79	7.05	-0.080	-4.18	2.33	-0.46	-0.20
79-80	-2.75	-0.110	4.38	0.32	-1.20	-3.75
80-81	-1.65	0.040	1.80	-5.04	-5.23	1.04
60-70	-0.11	0.010	0.40	0.18	-0.12	-0.67
70-81	0.32	0.008	-0.16	-0.38	-0.55	1.44

Table 4.11

DECOMPOSITION OF GROWTH RATE OF WEIGHTED TFP
Air Canada, CP Air and PWA
(%)

Years	Output	ASL	ATH	TFP	Unexplained	Unexplained TFP/ TFP
60-61	7.34	-4.72	-7.49	-5.39	-0.52	0.09
61-62	14.31	-0.39	-3.70	13.21	2.99	0.23
62-63	9.26	-0.07	1.51	10.99	0.29	0.03
63-64	-10.30	0.26	7.93	-4.48	-2.37	0.53
64-65	0.28	0.15	1.18	3.37	1.76	0.52
65-66	5.11	0.34	-1.83	1.51	-2.11	-1.40
66-67	2.03	0.14	-2.26	3.83	3.92	1.02
67-68	-6.21	0.23	2.98	-2.71	0.29	-0.11
68-69	-20.50	0.47	11.89	-0.70	7.44	-10.63
69-70	0.39	-0.04	-1.46	1.80	2.91	1.62
70-71	0.32	-0.54	1.24	0.36	-0.66	-1.83
71-72	0.94	0.07	0.07	3.16	2.08	0.66
72-73	0.47	0.10	0.07	1.00	0.36	0.36
73-74	-6.12	-0.20	4.30	-1.19	0.83	-0.70
74-75	-5.47	-0.22	1.63	-1.44	2.62	1.82
75-76	4.81	-0.07	-2.52	1.23	-0.99	-0.80
76-77	-4.63	0.17	3.52	-1.71	-0.77	0.45
77-78	1.62	-0.26	-9.77	0.62	9.03	14.56
78-79	3.69	-0.21	-3.15	4.20	3.87	0.92
79-80	-8.03	0.18	5.53	-0.71	1.61	-2.27
80-81	-6.59	0.06	2.58	-6.15	-2.20	0.36
60-70	0.17	0.06	0.87	2.14	1.04	0.49
70-81	-1.72	-0.08	1.12	-0.05	0.63	-12.60

Chapter 5

PARTIAL PRODUCTIVITY MEASURES

5.1 Definition and Limitations

Partial productivity measures are obtained by taking the ratio of output to individual classes of inputs. From the weighted average of the various partial productivity ratios, it is possible to derive a total factor productivity measure. As shown in Appendix B, other methodologies are usually used to derive total factor productivity measures, two of which being used in the previous two chapters. Having assessed the performance of Canadian air carriers with total factor productivity measures, it is logical to now consider the partial measures.

Partial productivity measures were the first type of productivity measures developed. The most popular was, and continues to some extent to be, the ratio of output to the associated labour inputs. The partial labour productivity measure is used here to caution readers about the uses of partial productivity measures. Labour is only one of the factor inputs. Therefore changes in the output/labour ratio (Q/L) are affected by changes of input mix as well as by changes in productive efficiency. The latter is measured by total factor productivity measures. If one designates total input by F, then partial labour productivity is defined as:

$$Q/L = Q/F \cdot F/L$$

In other words, rates of change in output per unit of labour input reflect rates of changes in both total factor productivity and total factor input per unit of labour input (factor intensity growth). As was said earlier, a partial labour productivity measure ignores all inputs but labour. Therefore, it is possible that output per unit of labour input rises faster (slower) than total factor productivity. Since total tangible factor input is a weighted average of the labour and other inputs, then the difference in rates of change between the labour and total factor input measures represents the rate of substitution of other inputs for labour (of labour for other inputs).

It should be remembered that the meaning of changes in the output/labour ratio depends on the actual definition of each term of the ratio and on their measurement. For instance, if undifferentiated hours worked and combined quantities of output are used, then the change in output per hour measured for an aggregate of products reflects relative shifts of production among products with differing ratios of factor costs or prices to hours as well as productivity changes in producing each of the products. The effect of production shifts among products on partial productivity ratios is eliminated by weighting the component output measures by their base-period requirements for the input to which output is being related.

Airlines' output measures can be related not only to primary factor inputs such as labour and capital but also to intermediate product inputs such as fuel and materials. Partial productivity measures should not be interpreted as measures of changes in efficiency of the particular input in the denominator. They are merely reflections of changes in the use of the given input per unit of output. Having said that, partial measurements of productivity actually calculated for Canadian air carriers are presented in the following sections of this chapter.

5.2 Labour Input

The labour input trend is measured by what is called in this study the Composite Labour Input Index (CLI). Table A.4.1 to A.4.7 in Appendix A present the CLI index. If one excludes Transair, total employment for Canadian air carriers increased at an average annual rate of growth which ranges between 3.8% and 9.1% over the period 1960 and 1981. Air Canada was the carrier which experienced the lowest annual rate of growth in its employment while Nordair had the highest annual growth rate. PWA saw its total employment increase at an average annual growth rate of 8.2% during that period, which was somewhat higher than the 5.9%, the 5.5% and the 5.0% that CP Air, EPA and Quebecair respectively averaged yearly from 1960 to 1981.

In the previous productivity study of Canadian air carriers, the period 1960 to 1976 was analysed. If one looks at what happens after 1976, it is possible to observe that carriers with relatively high yearly average growth in their total employment from 1960 to 1981 increased their employment during the 1977 to 1981 sub-period at a yearly rate which exceeded the rate observed for the whole period. CP Air, PWA and Nordair are three carriers who operated under such a scenario. Quebecair is the only carrier which decreased its total employment between 1977 and 1981. In fact, though, except for PWA and EPA all the other carriers decreased their total employment in 1981. Therefore the actual slowdown of the economy, which started in 1981, forced most airlines to make some adjustment to the employment structure within their firms.

5.2.1 Labour Productivity - ASM and/or RPM, ATM and/or RTM

Labour productivity can be calculated by relating traditional output measures of air services such as Available Seat-Miles (ASM), Revenue Passenger-Miles (RPM), Available Ton-Miles (ATM) and Revenue Ton-Miles (RTM) to the number of employees hired by each carrier. (ASM and ATM are reported by Air Canada and CP Air, not by the other carriers.) Such a measure presents the labour productivity in absolute terms. An absolute measure of labour productivity could turn out to be misleading when levels of productivity attained by a given carrier are compared to the levels achieved by another carrier, without accounting for differences in the employment structure and in the output. Such differences have, in most cases, nothing to do with the relative efficiency of a carrier's labour force.

The airline industry has been faced with technical changes since its birth. From 1960 onward, these changes were relatively important and Canadian carriers were able to take advantage of the new technology because of the steady growth of their traffic. Technical changes, such as the replacement of turboprop aircraft by jet technology, have resulted in major cost savings for the carriers. The increase in the size of the aircraft has also permitted improvements in the performance of air carriers. Thus, labour productivity increased over the years as new aircraft were introduced into carriers' fleets.

Table 5.1 shows the rise in Canadian air carrier labour productivity for selected years. For carriers such as Air Canada, CP Air and PWA, the increase in labour productivity cannot be disassociated from the advancement of the average take-off weight of their aircraft. The output measure used to measure the labour productivity is dependent on the network being served by the carriers, e.g., the distance separating city pairs. As carriers introduced bigger aircraft, they were able to fly longer distances. This is reflected in the average stage length statistics reported in Table A.2.3 of Appendix A. Therefore as the distances flown were increased, output, measured in revenue passenger-miles or available seat-miles, was increased partly because of that distance factor. For years such as 1981, it is possible to explain in part the improvement of ASM/employee for Air Canada by the increase in the average distances flown. CP Air managed to continue to show an improvement in its RPM/employee in 1981 by, among other things, achieving for that year a higher load factor on its flights. EPA is the regional carrier who managed to achieve in 1981, the best performance in terms of improvement of its labour productivity as measured by the RRM's/employee and by the RPM's/employee. On the other hand, Quebecair had to face for the same year, a serious deterioration of its labour productivity. Such a deterioration is serious since Quebecair made the decision to diminish its actual number of employees and such a decision was not sufficient to restore their employees' performance. Labour, however, is only one of the factors used in carriers' operations. Nordair, due to changes in the operation, experienced a drop in its labour productivity in 1981.

Table 5.1

LABOUR PRODUCTIVITY

	ASM/Employee (,000)		RPM/Employee (,000)						
Year	**AC**	**CP**	**AC**	**CP**	**PWA**	**Transair**	**Nordair**	**Quebecair**	**EPA**
1960	280	330	180	200	52	79	37	113	49
1968	580	760	340	380	321	158	264	141	73
1976	870	950	550	630	357	575	664	624	404
1981	979	991	619	774	418	-	623	535	496

	ATM/Employee (,000,000)		RTM/Employee (,000,000)						
Year	**AC**	**CP**	**AC**	**CP**	**PWA**	**Transair**	**Nordair**	**Quebecair**	**EPA**
1960	35.8	41.2	21.3	22.5	N/A	N/A	N/A	N/A	N/A
1968	87.7	109.6	43.3	48.3	46.7	25.0	43.2	17.6	12.9
1976	148.1	134.3	71.2	79.6	53.0	64.0	80.9	70.2	45.3
1981	157.0	139.3	78.3	85.3	37.6	-	43.5	18.6	52.7

Table 5.2

LABOUR PRODUCTIVITY GROWTH
Average Annual Percentage Rates

	CAO/CLI		CRO/CLI						
Period	**AC**	**CP**	**AC**	**CP**	**PWA**	**Transair**	**Nordair**	**Quebecair**	**EPA**
1960-1968	8.9	9.0	6.9	9.0	5.6	0.3	-2.7	1.3	-3.7
1968-1981	3.7	2.6	4.1	5.1	3.4	N/A	3.4	7.4	9.4
1960-1981	5.7	5.0	5.1	6.6	4.2	N/A	1.0	5.1	4.2
1977-1981	1.3	-0.4	1.8	1.5	1.4	N/A	-0.4	1.8	7.0

5.2.2 Labour Productivity - CAO and CRO

The reader will have noticed so far that the analysis has not related the passenger-miles or ton-miles per employee of an airline to the one of another. Purposely, such comparisons of airline efficiency were avoided because such partial measures of productivity do not take into account differences in the nature of each carrier's production. Therefore, without knowing the effects of the specificity of each carrier's production process, it is dangerous to associate partial measures of productivity to a measure of relative efficiency.

Such problems are attenuated but still present when the output measures used in the calculation of labour productivity are the Composite Available Output (CAO) and the Composite Revenue Output (CRO) and that the two said measures are related to the Composite Labour Input (CLI). The CAO and CRO output measures are defined in Chapter 3.

Looking at the labour productivity growth as defined above permits the verification of certain findings described in Section 5.2.1. EPA was the regional carrier which continued to improve its labour productivity in 1981. In fact, EPA achieved the highest growth in labour productivity over the 1977 to 1981 period as measured by CRO/CLI. If RPM/employee for Nordair in 1981 were lower than in 1976, the CRO/CLI growth over the 1977 to 1981 period was also negative. Quebecair shows an improvement in its labour productivity for that same period when the CRO/CLI measure is used while the RPM/employee indicated a deterioration of the labour performance. CP Air is a carrier which, despite a negative growth between 1977 and 1981 of the CAO/CLI measure of labour productivity, demonstrated an improvement in ASM per employee and in ATM per employee in 1981.

From Table 5.2, it is possible to derive some conclusions which are worth noticing. Air Canada and CP Air attained high growth of their labour productivity earlier than the regional carriers did. The labour performance is determined to some major extent by the type of equipment being used. The introduction of the jet technology has improved the efficiency of carriers' employees. But, as technological changes introduced in airline operations have become less dramatic and more gradual, major improvements in labour productivity have been exhausted. Therefore, the growth observed in the labour productivity has been significantly lower in recent years than the growth observed on average in the period under study.

5.3 Capital Input

The improvement in labour productivity has been associated to a large extent with the introduction of jet technology. Jet aircraft were larger and faster than the equipment they had replaced and, therefore, longer distance could be flown with the new aircraft. The previous productivity study entered into a discussion on the historical evolution of the technical characteristics of the aircraft being used by each carrier.*

The point which is important to remember is the following: as jet aircraft were used more and more by the carriers, their fleet characteristics changed. These changes in the key fleet characteristics are: increases in average speed, average take-off weight and stage length. These characteristics are presented yearly for each carrier for the period 1960 to 1981 in Tables A.2.1 to A.2.3 of Appendix A. For Air Canada and CP Air, the aircraft-utilization rate is also presented. This last characteristic is more a function of the network being served than of the type of aircraft being used, even though the type of aircraft and the network cannot be totally dissociated.

Table 5.3 gives a good indication of the effects of the introduction of the jet aircraft on the fleet characteristics. Carriers such as Air Canada, PWA, Quebecair and EPA more than doubled their average stage length from 1960 to 1981. If one adds Nordair to the list, one has an idea of the carriers who more than doubled their average take-off weight of their flight equipment over the same period. Therefore these major changes in carriers' fleets have completely transformed the nature of air services being offered. The service is also faster because the planes are faster. All in all, one cannot help but notice the fundamental changes that have taken place in the production of air services. As a result, the public has experienced major improvements in the quality of air transportation services made possible by major technological change.

The more recent technological changes in aircraft technology will not represent as significant cost savings to carriers as some of the earlier changes and therefore will not be accompanied by declining fares. As the Canadian airline industry is experiencing modest traffic growth, carriers have had to adjust their operations to maintain viable financial performance. The recent growth pattern of air services faced by Canadian air carriers has had an impact on the average aircraft utilization rate (Table A.2.4 of Appendix A). For instance, CP Air's aircraft utilization rate performance has been erratic over the 1960 to 1981 period. But the recent figures (1977-1981) show that the new environment under which CP Air has had to operate has forced this carrier to introduce some changes in its operations. As a result, during 1981 CP Air averaged over 150 less hours flown by aircraft than in 1980, 1979 was another year which resulted, for CP Air, in a drastic drop in the average

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* The reader interested in knowing when exactly each carrier has reduced its utilization of piston-engine planes and turboprop engine planes is referred to the said study.

Table 5.3

ROUTES AND FLEET CHARACTERISTICS COMPARISONS BETWEEN 1960 AND 1981

Carrier	Average Speed (m.p.h.)		Average Take-Off Weight (tons)		Stage Length (miles)	
	1960	1981	1960	1981	1960	1981
Air Canada	221	389	38	114	340	729
CP Air	267	415	61	149	635	921
PWA	127	335	13	55	151	305
Transair	126	N/A	11	N/A	131	N/A
Nordair	136	400	22	48	269	426
Quebecair	163	302	15	40	126	322
EPA	127	315	12	44	133	272

number of hours flown by aircraft. Air Canada experienced a comparable situation in 1980 and in 1981, two years which required downward adjustment to the utilization of aircraft. Surprisingly, Air Canada's aircraft utilization rate in 1981 was basically the same as the rate achieved in 1960. One should note that it was not until 1967 that Air Canada surpassed its 1960 aircraft utilization rate. Since 1960, Air Canada has faced wide variation in its aircraft utilization rate.

5.3.1 Trends in the Different Measures of Capital

In this study, three measures of capital are used: (1) number of aircraft, (2) number of aircraft hours flown and (3) number of aircraft ton-hours flown. For the three measures of capital, the average annual rates of growth are presented in Table 5.4 for selected periods. The growth in the aircraft ton-hours was higher for Air Canada and CP Air betwen 1960 and 1968 than it was over the 1968-1981 period. For regional carriers, the reverse situation was observed.

Looking at the aircraft hours flown, it is possible to associate the slowdown in their growth over certain years within the period under study to the introduction of jet equipment. Such equipment made a better utilization of the fleet possible. Being bigger, less hours flown were necessary to carry a given level of traffic. In the earlier CTC productivity study mentioned before, a statement was made which is still relevant today, namely: "the measure of aircraft hours has limited relevance over a period in which the average size of aircraft was increasing so substantially" (p. 54). Nevertheless, carriers significantly increased the average number of hours flown by aircraft while the average size of the aircraft grew modestly over the same period. One should notice that the actual number of aircraft in carriers' fleets grew between 1977 and 1981.

5.3.2 Capital Productivity

Tables A.6.3 to A.6.6 in Appendix A contain the partial productivity indices for capital. They are summarized in Table 5.5 below. Two of the three measures of capital, aircraft hours (AH) and aircraft ton-hours (ATH), were related to the output measures, Composite Revenue Output (CRO) and Composite Available Output (CAO) when possible. For both Air Canada and CP Air, it is possible to relate the capital measures to two measures of output, CAO and CRO. Capital measure for the regional carriers can only be related to the CRO measure of output.

Looking at the different partial productivity measures for the capital input of Air Canada and CP Air might be somewhat confusing. On the one hand, when capital productivity is measured in terms of either CAO/AH or CAO/ATH, Air Canada's performance surpassed that of CP Air. On the other hand, the

Table 5.4

AVERAGE ANNUAL PERCENTAGE RATES OF GROWTH

Number of Aircraft

Period	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	2.0	-0.1	-12.0	-9.5	-7.8	5.7	0.4
1968-1981	1.1	1.9	4.5	N/A	3.9	3.5	-9.3
1960-1981	1.4	3.2	-2.1	N/A	-0.7	4.3	-5.7
1977-1981	4.1	7.1	6.9	N/A	8.5	21.8	2.8

Aircraft Hours

Period	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	1.9	3.8	-5.8	2.0	-4.0	6.0	2.7
1968-1981	1.0	4.2	8.1	N/A	7.3	3.0	-1.1
1960-1981	1.3	4.0	2.6	N/A	2.8	4.1	0.3
1977-1981	3.5	5.1	8.6	N/A	5.8	-8.6	5.0

Aircraft Ton-Hours

Period	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	10.3	11.8	9.6	13.3	2.2	5.2	3.6
1968-1981	4.7	6.5	10.1	N/A	9.7	11.5	8.6
1960-1981	6.8	8.5	9.9	N/A	6.8	9.0	6.7
1977-1981	3.1	5.1	4.0	N/A	2.9	-10.8	3.7

Table 5.5

CAPITAL PRODUCTIVITY MEASURES
(%)

	CAO/AH		CRO/AH						
Period	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	13.1	11.7	11.0	11.6	13.2	5.8	4.6	0.5	1.4
1968-1981	5.3	4.1	5.6	6.6	7.9	N/A	8.9	9.4	14.9
1960-1981	8.2	6.9	7.7	8.5	9.9	N/A	7.2	5.9	9.6
1977-1981	1.3	1.3	1.9	3.2	3.6	N/A	4.9	4.2	4.0

	CAO/ATH		CRO/ATH						
Period	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	4.5	3.7	2.5	3.7	-2.6	-4.7	-1.7	1.2	0.6
1968-1981	1.6	1.7	1.9	4.2	5.9	N/A	6.5	1.1	4.6
1960-1981	2.7	2.5	2.1	4.0	2.6	N/A	3.3	1.1	3.1
1977-1981	1.6	1.4	2.2	3.1	7.9	N/A	7.8	7.0	5.3

CRO/AH and CRO/ATH measures indicate that CP Air outperformed Air Canada. Differences in the actual load factor achieved on the average by the two carriers during these years are responsible for the relative capital productivity performance achieved by each of the two carriers under different measures. Except for CP Air's CRO/ATH measure, the 1960 to 1968 period is responsible for a good portion of the increase in the two major carriers' capital productivity observed over the 1960 to 1981 period. Recently (1977-1981), the increases in capital productivity as measured in terms of available output have been relatively modest. The two carriers have put more emphasis on load factors which explains why the CRO/ATH measure indicates an annual growth for the 1977 to 1981 equivalent to the one observed for the whole 1960 to 1981 period.

The regional carriers have also, in recent years, filled a higher proportion of the seats on their flights. As a result, the CRO/ATH capital productivity measure has increased significantly between 1977 and 1981. Between 1960 and 1968, regional carriers were unable to achieve a high level of capital productivity. With the introduction of the Regional Air Carrier Policy it became possible to use bigger aircraft and therefore to serve markets which were previously either not accessible because of the range of aircraft used or not attractive to users because of the indirect nature of the services offered. In fact, the new policy permitted the introduction of jet equipment in their fleets which in turn made it possible to achieve a more productive utilization of the capital equipment.

5.4 Fuel Input

Fuel is the input which has received a great deal of attention since the energy crisis of 1973. Since then carriers have seen their fuel costs increase significantly. As a result, carriers have attempted to maximize the utility of that input. Therefore, the fuel productivity measure should indicate whether carriers have had any success in improving their utilization of fuel. Because more than one type of fuel was actually used by carriers at one point in time between 1960 and 1981, fuel was measured in terms of British Thermal Units (BTU) since it is the energy content and not so much the number of gallons which can indicate more clearly the performance in fuel use.

The fuel index in BTU's for Canadian air carriers increased at a much lower average annual rate between 1977 and 1981 than it did for the whole period of 1960-1981 (Table 5.6). This clearly indicates the recognition by the carriers of the importance of fuel conservation. The higher loads carried by jet aircraft were translated into increased demand for fuel, but as the fuel price increased, matching the supply to the demand for air services grew in importance in order to make a better use of fuel.

Table 5.6

AVERAGE ANNUAL PERCENTAGE RATES OF GROWTH
Fuel Input (BTU)

Period	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	14.1	16.7	15.4	15.9	6.3	8.7	5.4
1968-1981	3.6	6.2	14.8	N/A	17.1	11.4	14.6
1960-1981	7.5	10.1	15.0	N/A	12.8	10.4	11.0
1977-1981	2.8	3.5	7.0	N/A	5.6	-12.8	2.1

Table 5.7

FUEL PRODUCTIVITY GROWTH
Average Annual Percentage Rates

	CAO/Fuel		CRO/Fuel						
Period	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	1.0	-0.6	-0.9	-0.8	-7.6	-6.8	-5.4	-2.2	-1.2
1968-1981	2.7	2.1	3.0	4.6	1.6	N/A	-0.4	1.2	-0.8
1960-1981	2.0	1.0	1.5	2.5	-2.0	N/A	-2.3	-0.1	-0.9
1977-1981	2.1	2.8	2.7	4.6	4.7	N/A	5.1	9.2	7.2

5.4.1 Fuel Productivity

All the statements made so far regarding the carriers' recent consciousness that an efficient utilization of their fuel input is necessary for their financial viability is corroborated by the average annual percentage rate of growth observed by all carriers in their fuel productivity indices. EPA, Nordair, Quebecair and PWA all managed to improve their performance in using fuel productively between 1977 and 1981. Air Canada and CP Air also managed to improve their output per BTU over the same period. In fact, the figures of Table 5.7 seem to indicate that Air Canada and CP Air became aware of the importance of an efficient use of fuel sooner than did the regional carriers. A more efficient utilization of fuel is not an easy task. It requires a close examination of the schedule, and the network and adjustments to these two important parameters in airline operations are complex. Therefore such adjustments might be more accessible to a big airline than to a small one, the former having greater resources to devote to the problem.

5.5 Material Productivity

Material is one of those inputs which is an aggregation of heterogeneous inputs. With the exception of labour, capital and fuel, it includes all other inputs entering into the production process of air services. To talk of the productivity of the material input could be somewhat elusive since it is not possible to associate any improvement or deterioration of material productivity with any of the inputs included in the input called "material". This explains why material was measured in terms of dollars, since it was the only common unit with which these inputs could be aggregated. Even though an index of material was calculated, such measure of material inputs still has disadvantages.

Material is the input which underwent the most significant average growth between 1977 and 1981 (Table 5.8). If carriers were able to generate more output per unit of energy consumption and to maintain a positive productivity with respect to labour and to capital between these recent years, it has not been the case for material (Table 5.9). In fact, Nordair was the only carrier who was able to achieve a positive average annual rate of productivity growth for its material input. The figures clearly indicate that in recent years, carriers have been increasing their utilization of material in their production process at a faster rate than their output growth. As a result, the productivity of material has become negative for all carriers, with Nordair being the only exception.

Table 5.8

AVERAGE ANNUAL PERCENTAGE RATES OF GROWTH
Material Input

Period	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	10.2	9.9	8.8	11.7	0.5	2.0	7.2
1968-1981	6.2	7.1	14.8	N/A	17.3	13.6	15.2
1960-1981	7.7	8.2	12.5	N/A	10.6	9.0	12.1
1977-1981	10.1	8.9	26.0	N/A	10.2	-0.7	23.2

Table 5.9

MATERIAL PRODUCTIVITY GROWTH
Average Annual Percentage Rates

	CAO/MAT		CRO/MAT						
Period	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960-1968	4.6	5.5	2.6	5.5	-1.9	-3.4	0.0	4.3	2.7
1968-1981	0.1	1.2	0.5	3.6	1.6	-3.8	-0.6	-0.7	-1.5
1960-1981	1.8	2.8	1.3	4.3	0.2	-3.6	-0.3	1.1	-2.0
1977-1981	-4.9	-2.2	-4.1	-0.5	-10.8	N/A	0.5	-4.2	-11.4

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APPENDICES

Appendix A

TABLES

Table A.1.1

ABSOLUTE VALUE MEASURES OF INPUTS, AIR CANADA AND CP AIR
1960-1981

	Air Canada						CP Air					
Year	**L**	**NA**	**AH**	**ATH**	**FBTU**	**MAT**	**L**	**NA**	**AH**	**ATH**	**FBTU**	**MAT**
1960	11 195	93	266	10 056	13 994	61 465	2 683	22	49	2 998	3 300	21 055
1961	11 731	85	208	10 360	18 201	66 533	3 704	24	50	3 480	4 689	22 614
1962	11 917	83	191	10 920	19 549	71 192	2 537	20	47	3 840	5 792	26 241
1963	11 587	78	182	11 684	20 777	77 286	2 638	22	49	4 428	6 871	29 391
1964	11 634	77	184	12 159	21 767	86 227	2 634	18	44	4 322	7 046	28 672
1965	12 253	78	206	14 141	25 125	101 832	2 805	17	48	4 720	7 669	34 608
1966	13 718	84	238	16 442	29 591	118 653	3 188	16	53	5 316	8 816	37 080
1967	15 823	93	293	19 553	35 575	132 293	3 806	20	61	6 082	10 308	43 240
1968	16 791	109	308	22 006	40 159	133 992	4 301	22	66	7 319	11 395	44 930
1969	16 395	110	287	22 414	40 759	134 352	4 826	21	72	8 126	14 126	52 807
1970	17 688	111	306	26 946	47 153	160 986	5 175	20	80	8 934	15 972	58 590
1971	17 507	108	292	27 103	47 943	155 064	5 386	22	81	8 816	14 649	55 313
1972	17 830	103	291	28 369	50 514	168 742	5 461	23	82	8 709	16 032	56 443
1973	19 512	107	315	32 488	57 435	191 367	5 685	24	86	9 222	16 904	57 434
1974	21 326	110	321	34 587	60 625	202 984	7 208	26	102	12 891	21 212	72 188
1975	21 053	118	331	36 545	61 288	193 019	7 696	29	103	14 334	22 729	78 930
1976	20 841	118	324	36 209	59 727	202 703	7 338	29	99	14 054	21 888	78 722
1977	20 364	107	306	35 472	57 159	199 543	6 855	25	92	13 659	21 545	77 988
1978	20 459	106	315	36 969	57 683	225 388	6 989	24	92	13 835	21 670	85 458
1979	21 875	115	349	41 551	64 696	257 945	7 573	31	101	14 918	23 708	96 135
1980	23 316	124	365	41 514	65 616	283 899	10 252	30	100	16 348	25 641	106 611
1981	23 200	126	353	40 129	63 643	293 993	8 920	33	112	16 658	24 750	109 789

L: number of employees
NA: number of aircraft
AH: number of aircraft hours (,000)
ATH: number of aircraft ton-hours (,000)
FBTU: fuel in British Thermal Units (,000,000,000)
MAT: purchases of materials, other than fuel, and services (in constant 1971 dollars (,000))

Source: Aviation Statistics Centre.

Table A.1.2

ABSOLUTE VALUE MEASURES OF INPUTS, PWA AND TRANSAIR
1960-1981

	PWA						Transair					
Year	L	NA	AH	ATH	FBTU	MAT	L	NA	AH	ATH	FBTU	MAT
1960	628	45	44	561	453	3 475	206	29	16	172	142	1 156
1961	473	42	37	407	324	2 736	252	30	19	311	259	1 836
1962	444	42	31	354	299	2 517	311	24	22	399	327	2 313
1963	406	39	31	400	342	2 712	345	26	25	450	408	2 486
1964	475	47	37	646	536	3 678	312	25	23	400	375	2 180
1965	529	48	44	820	694	4 881	311	23	23	413	423	1 755
1966	559	34	34	903	754	5 116	356	21	23	489	482	3 008
1967	631	25	32	933	988	6 043	345	12	18	436	392	2 644
1968	703	16	27	1 170	1 427	6 824	367	13	18	467	462	2 807
1969	1 065	22	35	1 782	2 772	11 317	431	12	24	599	658	4 155
1970	1 237	23	35	1 953	3 300	14 927	395	15	22	614	826	3 832
1971	1 328	25	44	2 168	3 633	13 027	396	10	19	599	907	5 395
1972	1 551	20	45	2 330	4 122	14 651	434	11	17	579	1 188	4 270
1973	1 809	21	51	2 846	5 260	17 849	607	13	21	754	1 741	5 454
1974	2 085	24	53	3 148	5 700	19 899	652	9	20	895	2 077	6 559
1975	2 215	23	52	3 307	6 061	20 177	637	11	19	867	2 007	6 774
1976	2 245	23	48	2 981	5 566	16 397	702	8	21	1 029	2 346	6 912
1977	2 376	22	54	3 484	6 556	16 308	706	7	21	854	2 186	6 648
1978	2 428	19	54	3 471	4 435	21 566	706	7	24	939	2 426	7 248
1979	2 581	23	57	3 380	6 494	24 881	699	7	18	814	2 047	5 500
1980	3 489	25	73	4 009	6 107	34 012	-	-	-	-	-	-
1981	3 669	29	75	4 086	8 609	41 160	-	-	-	-	-	-

L: number of employees
NA: number of aircraft
AH: number of aircraft hours (,000)
ATH: number of aircraft ton-hours (,000)
FBTU: fuel in British Thermal Units (,000,000,000)
MAT: purchases of materials, other than fuel, and services (in constant 1971 dollars (,000))

Source: Aviation Statistics Centre.

Table A.1.3

ABSOLUTE VALUE MEASURES OF INPUTS, NORDAIR AND QUEBECAIR
1960-1981

	Nordair						Quebecair					
Year	L	NA	AH	ATH	FBTU	MAT	L	NA	AH	ATH	FBTU	MAT
1960	216	21	19	416	327	2 103	276	9	13	190	271	1 752
1961	276	19	25	495	394	2 614	317	9	9	160	263	1 714
1962	249	14	19	346	308	1 942	283	8	11	169	267	1 404
1963	204	20	15	284	225	1 457	275	9	11	168	260	1 557
1964	233	20	17	370	296	1 759	281	9	11	169	272	1 522
1965	256	20	18	487	409	2 486	297	13	12	184	284	1 664
1966	300	20	18	546	444	2 599	367	14	16	242	372	2 081
1967	326	20	15	478	382	2 274	369	11	16	254	392	1 669
1968	283	11	14	493	534	2 182	395	14	20	285	530	2 056
1969	312	9	16	522	822	3 128	409	10	18	355	995	2 896
1970	412	13	17	593	1 019	3 715	413	8	16	342	892	2 738
1971	457	18	23	725	1 315	4 780	442	20	20	444	951	3 232
1972	578	24	29	915	1 685	6 135	448	6	21	459	975	3 216
1973	730	20	33	1 154	2 140	7 256	483	7	23	561	1 265	3 714
1974	866	19	32	1 259	2 405	9 177	637	10	26	748	1 579	4 890
1975	909	20	32	1 356	2 726	10 594	877	10	34	1 502	3 125	8 926
1976	911	15	31	1 505	3 460	11 563	850	10	34	1 424	2 908	9 025
1977	856	13	27	1 463	3 334	11 850	949	10	42	1 856	3 739	11 013
1978	885	14	28	1 523	3 399	11 942	1 016	9	45	2 030	3 776	13 148
1979	1 155	16	37	2 247	4 740	18 546	1 003	6	43	1 717	3 240	11 481
1980	1 655	16	36	1 854	4 363	17 474	849	8	32	1 060	1 917	8 904
1981	1 301	18	34	1 641	4 138	17 465	933	22	30	1 173	2 166	10 729

L: number of employees
NA: number of aircraft
AH: number of aircraft hours (,000)
ATH: number of aircraft ton-hours (,000)
FBTU: fuel in British Thermal Units (,000,000,000)
MAT: purchases of materials, other than fuel, and services (in constant 1971 dollars (,000))

Source: Aviation Statistics Centre.

Table A.1.4

ABSOLUTE VALUE MEASURES OF INPUTS, EPA 1960-1981

Year	L	NA	AH	ATH	FBTU	MAT
1960	257	34	24	289	282	1 947
1961	306	34	26	307	331	2 477
1962	354	38	27	356	330	2 679
1963	365	37	27	310	353	2 719
1964	397	26	27	329	380	2 976
1965	440	31	24	312	360	2 091
1966	448	33	28	312	352	2 630
1967	482	34	32	340	388	3 049
1968	500	35	29	384	430	3 379
1969	539	32	30	477	721	4 046
1970	528	25	25	525	1 059	5 235
1971	513	11	19	590	1 181	6 242
1972	513	11	20	667	1 397	6 279
1973	599	12	21	805	1 811	7 161
1974	708	10	23	956	2 609	8 637
1975	835	11	22	992	2 353	8 681
1976	826	9	21	968	2 288	8 653
1977	827	9	21	970	2 320	9 315
1978	875	9	22	1 037	2 446	9 605
1979	869	9	22	1 060	2 519	11 314
1980	883	9	24	1 123	2 582	15 147
1981	890	10	25	1 121	2 516	21 436

L: number of employees
NA: number of aircraft
AH: number of aircraft hours (,000)
ATH: number of aircraft ton-hours (,000)
FBTU: fuel in British Thermal Units (,000,000,000)
MAT: purchases of materials, other than fuel, and services (in constant 1971 dollars (,000))

Source: Aviation Statistics Centre.

Table A.2.1

FLEET CHARACTERISTIC AS MEASURED BY AVERAGE SPEED
1960-1981

Year	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960	221	267	127	126	136	163	127
1961	256	289	115	143	143	180	125
1962	274	320	127	150	145	177	122
1963	287	344	131	153	129	179	123
1964	292	360	142	151	135	171	117
1965	295	355	146	152	142	170	114
1966	303	364	165	154	154	166	108
1967	308	372	184	160	170	163	107
1968	326	373	224	170	194	157	115
1969	345	428	286	179	239	188	138
1970	358	441	314	206	256	195	177
1971	354	426	266	237	257	206	231
1972	359	424	283	246	259	210	245
1973	367	427	291	272	246	223	262
1974	372	420	298	320	267	237	281
1975	381	418	309	311	278	269	296
1976	384	422	315	327	323	266	304
1977	383	425	322	323	362	273	304
1978	383	422	314	328	363	266	306
1979	382	419	304	326	385	249	310
1980	383	417	311	-	368	246	299
1981	389	415	335	-	400	302	315

Average Speed = Revenue Miles/Revenue Hours (in m.p.h.).

Source: Aviation Statistics Centre.

Table A.2.2

FLEET CHARACTERISTIC AS MEASURED BY AVERAGE TAKE-OFF WEIGHT
1960-1981

Year	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960	38	61	13	11	22	15	12
1961	50	70	11	16	20	18	12
1962	57	81	12	18	18	16	13
1963	64	91	13	18	19	16	11
1964	66	99	17	18	22	15	12
1965	68	98	19	18	27	16	13
1966	69	100	26	21	31	16	11
1967	67	99	29	24	32	16	11
1968	71	111	43	25	36	14	13
1969	78	113	50	25	32	20	16
1970	88	111	55	28	34	22	21
1971	93	108	49	32	32	22	32
1972	97	106	52	33	32	22	34
1973	103	107	56	36	36	24	38
1974	108	126	59	45	39	28	41
1975	110	139	63	44	42	44	45
1976	112	142	62	48	49	42	47
1977	116	148	65	40	47	44	47
1978	117	150	64	40	54	45	47
1979	119	148	59	46	61	40	48
1980	114	149	55	-	51	33	47
1981	114	149	55	-	48	40	44

Average Take-Off Weight = Aircraft Ton-Hours/Aircraft Hours (in tons).

Source: Aviation Statistics Centre.

Table A.2.3

ROUTE CHARACTERISTIC AS MEASURED BY STAGE LENGTH
1960-1981

Year	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1960	340	635	151	131	269	126	133
1961	351	620	136	188	201	129	131
1962	360	641	122	212	180	140	132
1963	377	716	124	205	203	140	127
1964	389	691	138	199	276	139	131
1965	401	712	150	200	320	137	130
1966	427	740	185	197	341	127	124
1967	451	790	208	211	323	129	130
1968	493	769	262	244	362	123	135
1969	524	956	318	257	402	152	160
1970	544	1 022	315	281	458	142	191
1971	548	978	253	270	408	175	208
1972	554	950	260	301	422	190	223
1973	570	991	265	332	396	199	215
1974	579	937	270	407	415	222	231
1975	613	919	270	389	410	262	244
1976	623	964	265	436	476	247	239
1977	636	1 012	280	426	510	268	243
1978	663	953	270	445	497	262	245
1979	693	938	266	437	498	243	257
1980	710	946	287	-	407	234	259
1981	729	921	305	-	426	322	272

Stage Length = Revenue Miles/Revenue Departure (in miles per departure).

Source: Aviation Statistics Centre.

Table A.2.4

ROUTE AND FLEET CHARACTERISTICS OF AIR CANADA AND CP AIR PASSENGER LOAD FACTOR AND AIRCRAFT UTILIZATION RATE 1960-1981

	Air Canada		CP Air	
Year	Passenger Load Factor (%)	Aircraft Utilization Rate	Passenger Load Factor (%)	Aircraft Utilization Rate
1960	65	2 797	58	2 112
1961	64	2 374	51	1 965
1962	60	2 249	50	2 276
1963	59	2 289	47	2 156
1964	63	2 385	53	2 359
1965	65	2 584	56	2 758
1966	66	2 719	56	3 132
1967	65	3 029	56	2 879
1968	57	2 823	50	2 874
1969	57	2 558	50	3 276
1970	57	2 711	52	3 877
1971	55	2 664	55	3 610
1972	65	2 767	63	3 471
1973	67	2 890	63	3 440
1974	63	2 866	61	3 816
1975	59	2 774	59	3 493
1976	60	2 710	61	3 344
1977	61	2 862	64	3 686
1978	59	2 971	69	3 832
1979	65	3 036	70	3 245
1980	67	2 947	70	3 653
1981	65	2 799	69	3 396

Passenger Load Factor = Unit-Toll RPM/Unit-Toll ASM
Aircraft Utilization Rate = Revenue Hours/Number of Aircraft
(in hours per airplane)

Source: Aviation Statistics Centre.

Table A.3.1

REVENUE HOURS BY TYPE OF AIRCRAFT, AIR CANADA AND CP AIR, 1960-1981

	Pistons		Turboprop		Jets		Total	
Year	AC	CP	AC	CP	AC	CP	AC	CP
1960	110 265	23 880	142 896	22 577	6 992	-	260 153	46 457
	(42.4)	(51.4)	(54.9)	(48.6)	(2.7)	-		
1961	26 639	22 917	147 657	17 406	27 549	6 840	201 755	47 163
	(13.2)	(48.6)	(73.2)	(36.9)	(13.6)	(14.5)		
1962	3 893	17 098	149 098	12 844	33 711	15 581	186 702	45 523
	(2.1)	(37.6)	(79.9)	(28.2)	(18.1)	(34.2)		
1963	1 354	16 215	135 546	11 888	41 631	19 338	178 531	47 441
	(0.8)	(34.2)	(75.9)	(25.1)	(23.3)	(40.8)		
1964	-	15 918	135 857	3 710	44 570	22 829	180 427	42 457
	-	(37.5)	(75.3)	(8.7)	(24.7)	(53.8)		
1965	-	17 419	147 013	4 827	54 513	24 543	201 526	46 789
	-	(37.2)	(72.9)	(10.3)	(27.1)	(52.5)		
1966	-	20 045	156 390	165	71 997	29 898	228 387	50 108
	-	(40.0)	(68.5)	(0.3)	(31.5)	(59.7)		
1967	-	21 171	176 083	753	105 593	35 664	281 676	57 588
	-	(36.8)	(62.5)	(1.3)	(37.5)	(61.9)		
1968	-	21 385	152 416	-	149 105	41 836	301 521	63 221
	-	(33.8)	(50.5)	-	(49.5)	(66.2)		
1969	-	2 452	101 403	-	179 931	66 336	281 334	68 788
	-	(3.6)	(36.0)	-	(64.0)	(96.4)		
1970	-	6	81 605	-	219 292	77 529	300 897	77 535
	-	(0.0)	(27.1)	-	(72.9)	(100.0)		
1971	-	-	59 337	-	228 414	79 419	287 751	79 419
	-	-	(20.6)	-	(79.4)	(100.0)		
1972	-	-	34 094	-	250 901	79 824	284 751	79 824
	-	-	(12.0)	-	(88.0)	(100.0)		
1973	-	-	14 599	-	294 624	82 560	309 223	82 560
	-	-	(4.7)	-	(95.3)	(100.0)		
1974	-	-	3 568	-	311 682	99 216	315 250	99 216
	-	-	(1.1)	-	(98.9)	(100.0)		
1975	-	-	-	-	327 278	101 283	327 278	101 283
	-	-	-	-	(100.0)	(100.0)		
1976	-	-	-	-	319 734	96 962	319 734	96 962
	-	-	-	-	(100.0)	(100.0)		
1977	-	-	-	-	306 276	92 149	306 276	92 149
	-	-	-	-	(100.0)	(100.0)		
1978	-	-	-	-	314 919	91 966	314 919	91 966
	-	-	-	-	(100.0)	(100.0)		
1979	-	-	-	-	349 191	100 585	349 191	100 585
	-	-	-	-	(100.0)	(100.0)		
1980	-	-	-	-	365 367	109 578	365 367	109 578
	-	-	-	-	(100.0)	(100.0)		
1981	-	-	-	-	352 625	112 064	352 625	112 064
	-	-	-	-	(100.0)	(100.0)		

Note: The percentage of total airline revenue hours is in parentheses.

Source: Aviation Statistics Centre.

Table A.3.2

TOTAL AND PERCENTAGE TON-HOURS FLOWN BY TYPE OF AIRCRAFT, 1960-1981 - REGIONAL CARRIERS

	Pistons				
Year	PWA	Transair	Nordair (thousands)	Quebecair	EPA
1960	560 903 (100.0)	181 947 (100.0)	415 959 (100.0)	81 951 (43.0)	253 183 (87.5)
1961	407 322 (100.0)	311 151 (100.0)	495 418 (100.0)	26 237 (16.4)	297 595 (96.8)
1962	354 254 (100.0)	398 754 (100.0)	310 363 (89.7)	41 763 (24.7)	343 780 (96.6)
1963	399 819 (100.0)	408 531 (90.8)	283 904 (100.0)	41 469 (24.7)	258 708 (83.6)
1964	645 937 (100.0)	348 831 (87.3)	370 021 (100.0)	41 916 (24.7)	200 469 (60.9)
1965	819 751 (100.0)	345 086 (83.5)	487 484 (100.0)	45 374 (24.6)	196 582 (63.0)
1966	884 117 (97.9)	425 672 (87.0)	545 694 (100.0)	62 414 (25.8)	213 136 (68.3)
1967	723 820 (77.6)	380 322 (87.2)	478 451 (100.0)	58 505 (23.0)	225 995 (66.4)
1968	539 846 (42.6)	365 955 (78.4)	379 678 (77.0)	36 676 (12.9)	267 701 (69.8)
1969	565 543 (31.7)	351 418 (58.6)	240 276 (46.0)	19 185 (5.4)	225 805 (47.4)
1970	281 952 (14.4)	197 847 (32.2)	156 096 (26.3)	30 810 (9.0)	117 781 (22.4)
1971	221 654 (10.2)	90 443 (15.1)	151 167 (20.9)	48 991 (11.0)	117 671 (20.0)
1972	59 109 (2.5)	39 228 (6.8)	192 669 (21.0)	46 090 (10.0)	79 220 (11.9)
1973	12 763 (0.4)	20 232 (2.7)	107 645 (9.3)	53 366 (9.5)	24 148 (3.0)
1974	2 099 (0.1)	0 (0.0)	47 312 (3.8)	52 930 (7.1)	21 499 (2.2)
1975	0 (0.0)	0 (0.0)	23 551 (1.7)	43 729 (2.9)	25 834 (2.2)
1976	0 (0.0)	0 (0.0)	9 418 (0.6)	27 415 (1.9)	6 600 (0.7)
1977	0 (0.0)	0 (0.0)	6 (0.0)	376 573 (20.3)	0 (0.0)
1978	0 (0.0)	0 (0.0)	0 (0.0)	25 112 (1.2)	0 (0.0)
1979	0 (0.0)	0 (0.0)	0 (0.0)	367 564 (21.4)	0 (0.0)
1980	0 (0.0)	- -	0 (0.0)	247 299 (23.3)	0 (0.0)
1981	0 (0.0)	- -	0 (0.0)	196 906 (16.9)	0 (0.0)

Note: The percentage is in parentheses.

Source: Aviation Statistics Centre.

Table A.3.2 (cont'd)

TOTAL AND PERCENTAGE TON-HOURS FLOWN BY TYPE OF AIRCRAFT, 1960-1981 - REGIONAL CARRIERS

	Turboprop				
Year	PWA	Transair	Nordair (thousands)	Quebecair	EPA
1960	0	0	0	108 437	36 116
	(0.0)	(0.0)	(0.0)	(57.0)	(12.5)
1961	0	0	0	133 757	9 879
	(0.0)	(0.0)	(0.0)	(83.6)	(3.2)
1962	0	0	35 483	127 275	12 074
	(0.0)	(0.0)	(10.3)	(75.3)	(3.4)
1963	0	41 368	0	126 129	50 850
	(0.0)	(9.2)	(0.0)	(75.3)	(16.4)
1964	0	50 921	0	127 490	128 694
	(0.0)	(12.7)	(0.0)	(75.3)	(39.1)
1965	0	68 013	0	138 717	115 533
	(0.0)	(16.5)	(0.0)	(75.4)	(37.0)
1966	18 913	63 740	0	179 149	99 151
	(2.1)	(13.0)	(0.0)	(74.2)	(31.7)
1967	197 243	56 011	0	195 649	114 405
	(21.1)	(12.8)	(0.0)	(77.0)	(33.6)
1968	353 234	100 695	0	248 028	115 847
	(30.2)	(21.6)	(0.0)	(87.1)	(30.1)
1969	555 944	247 882	0	196 616	128 178
	(31.2)	(41.4)	(0.0)	(55.3)	(26.9)
1970	635 441	232 311	1 768	114 949	101 931
	(32.5)	(37.8)	(0.3)	(33.6)	(19.4)
1971	991 547	218 766	19 192	159 061	102 265
	(45.7)	(36.5)	(2.6)	(35.9)	(17.3)
1972	1 092 662	198 312	78 420	179 983	114 188
	(46.9)	(34.2)	(8.6)	(39.2)	(17.1)
1973	1 061 350	225 762	349 249	166 044	114 594
	(37.3)	(29.9)	(30.3)	(29.6)	(14.2)
1974	1 069 162	130 045	351 125	227 680	99 210
	(34.0)	(14.5)	(27.9)	(30.5)	(10.4)
1975	828 014	85 645	362 230	326 213	48 401
	(25.0)	(9.9)	(26.7)	(21.7)	(4.9)
1976	576 898	97 529	284 089	329 270	54 090
	(19.4)	(9.5)	(18.9)	(23.1)	(5.6)
1977	614 297	279 207	210 001	574 359	76 332
	(17.6)	(32.7)	(14.4)	(31.0)	(7.9)
1976	524 616	317 542	218 326	641 172	79 339
	(15.1)	(33.8)	(14.3)	(31.6)	(7.6)
1979	535 760	112 963	216 436	632 090	59 257
	(15.9)	(13.9)	(9.6)	(36.9)	(5.6)
1980	364 688	-	210 008	400 036	81 459
	(9.1)	-	(11.3)	(37.7)	(7.3)
1981	326 088	-	68 336	298 090	119 847
	(8.0)	-	(4.2)	(25.4)	(10.7)

Source: Aviation Statistics Centre.

Table A.3.2 (cont'd)

TOTAL AND PERCENTAGE TON-HOURS FLOWN BY TYPE OF AIRCRAFT, 1960-1981 - REGIONAL CARRIERS

	Jet				
Year	PWA	Transair	Nordair (thousands)	Quebecair	EPA
1960	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1961	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1962	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1963	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1964	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1965	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1966	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1967	12 054 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1968	276 636 (23.6)	0 (0.0)	113 360 (23.0)	0 (0.0)	0 (0.0)
1969	660 154 (37.1)	0 (0.0)	281 870 (54.0)	139 699 (39.3)	122 628 (25.7)
1970	1 035 901 (53.0)	183 674 (29.9)	435 195 (73.4)	196 684 (57.4)	305 631 (58.2)
1971	955 195 (44.1)	290 041 (48.4)	554 583 (76.5)	235 515 (53.1)	369 716 (62.7)
1972	1 178 529 (50.6)	341 791 (59.0)	644 235 (70.4)	233 424 (50.8)	473 941 (71.0)
1973	1 771 674 (62.3)	508 416 (67.4)	697 377 (60.4)	341 355 (60.9)	665 890 (82.8)
1974	2 076 762 (66.0)	765 222 (85.5)	860 227 (68.3)	466 902 (62.5)	835 479 (87.4)
1975	2 479 216 (75.0)	781 046 (90.1)	970 240 (71.6)	1 132 443 (75.4)	921 280 (92.9)
1976	2 403 958 (80.6)	931 815 (90.5)	1 211 468 (80.5)	1 067 369 (75.0)	907 098 (93.7)
1977	2 869 580 (82.4)	575 015 (67.3)	1 253 348 (85.6)	904 825 (48.8)	893 529 (92.1)
1978	2 946 005 (84.9)	621 761 (66.2)	1 304 359 (85.7)	1 364 110 (67.2)	958 074 (92.4)
1979	2 844 007 (84.1)	700 722 (86.1)	2 030 204 (90.4)	717 223 (41.8)	1 001 087 (94.4)
1980	3 644 506 (90.9)		1 643 533 (88.7)	412 897 (38.9)	1 041 376 (92.7)
1981	3 760 010 (92.0)		1 572 882 (95.8)	667 989 (57.8)	1 001 106 (89.3)

Source: Aviation Statistics Centre.

Table A.4.1

OUTPUTS AND INPUTS, INDICES, AIR CANADA, 1960-1981
(1960=100)

Year	CAO	CRO	CLI	NA	AH	ATH	FBTU	MAT	TFI I	TFI II
1960	100	100	100	100	100	100	100	100	100	100
1961	124	118	104	92	78	103	130	108	103	108
1962	143	128	111	89	72	109	140	116	107	115
1963	153	137	108	84	68	116	148	126	108	119
1964	162	150	108	83	69	121	156	140	112	125
1965	190	178	113	84	78	141	180	166	126	141
1966	215	203	127	91	90	164	211	193	144	163
1967	261	246	147	100	110	194	254	215	168	188
1968	311	268	157	117	116	219	287	218	176	201
1969	327	279	151	118	108	223	291	219	172	199
1970	392	329	163	119	115	268	337	262	192	228
1971	399	331	161	116	110	270	343	252	188	225
1972	412	384	163	111	[illegible]	282	361	275	195	236
1973	484	459	179	115	[illegible]	323	410	311	215	265
1974	531	480	193	118	[illegible]	344	433	333	229	284
1975	573	478	192	127	124	363	438	314	226	282
1976	576	490	194	127	122	360	427	330	228	285
1977	574	504	190	115	115	353	408	325	221	278
1978	633	527	190	114	118	368	412	367	231	291
1979	689	610	204	124	131	413	462	420	256	323
1980	707	641	219	133	137	413	469	462	273	342
1981	696	624	218	135	132	399	455	478	272	341

CAO = Composite Available Output
CRO = Composite Revenue Output
CLI = Composite Labour Input
NA = Number of Aircraft
AH = Number of Aircraft Hours (revenue and non-revenue)
ATH = Number of Aircraft Ton-hours (revenue and non-revenue)
FBTU = Fuel in British Thermal Units
MAT = Purchases of Materials, Other than Fuel, and Services (in constant 1971 dollars)
TFI I = Total Factor Inputs Using Aircraft Hours as measure of Capital
TFI II = Total Factor Inputs Using Aircraft Ton-hours as measure of Capital

Source: Aviation Statistics Centre.

Table A.4.2

OUTPUTS AND INPUTS, INDICES, CP AIR, 1960-1981
(1960=100)

Year	CAO	CRO	CLI	NA	AH	ATH	FBTU	MAT	TFI I	TFI II
1960	100	100	100	100	100	100	100	100	100	100
1961	124	110	101	109	102	116	142	107	109	110
1962	157	139	96	90	96	128	176	125	118	120
1963	185	160	101	97	100	148	208	140	130	134
1964	180	176	101	80	89	144	214	136	126	133
1965	198	209	107	77	98	157	232	164	143	150
1966	224	241	122	73	109	177	267	176	158	166
1967	264	286	146	92	125	203	312	205	184	194
1968	327	326	164	99	135	244	345	213	199	214
1969	412	417	181	97	147	271	428	251	227	246
1970	467	486	193	89	164	298	484	278	250	270
1971	456	505	200	98	167	294	444	263	246	264
1972	448	564	204	102	168	290	486	268	252	270
1973	483	592	214	109	177	308	512	272	262	280
1974	656	786	270	118	209	430	643	346	328	359
1975	743	875	288	132	211	478	689	375	349	388
1976	734	899	275	132	203	469	663	374	339	377
1977	726	919	257	114	188	456	653	370	327	365
1978	734	1 003	261	109	188	462	657	406	339	379
1979	791	1 093	283	141	206	498	718	457	373	417
1980	883	1 220	377	136	224	545	777	506	434	485
1981	932	1 264	334	150	229	556	750	521	419	468

CAO = Composite Available Output
CRO = Composite Revenue Output
CLI = Composite Labour Input
NA = Number of Aircraft
AH = Number of Aircraft Hours (revenue and non-revenue)
ATH = Number of Aircraft Ton-hours (revenue and non-revenue)
FBTU = Fuel in British Thermal Units
MAT = Purchases of Materials, Other than Fuel, and Services (in constant 1971 dollars)
TFI I = Total Factor Inputs Using Aircraft Hours as measure of Capital
TFI II = Total Factor Inputs Using Aircraft Ton-hours as measure of Capital

Source: Aviation Statistics Centre.

Table A.4.3

OUTPUTS AND INPUTS, INDICES, PWA, 1960-1981
(1960=100)

Year	CRO	CLI	NA	AH	ATH	FBTU	MAT	TFI I	TFI II
1960	100	100	100	100	100	100	100	100	100
1961	83	75	93	84	73	72	79	77	75
1962	81	71	93	70	63	66	72	71	70
1963	88	65	87	72	71	75	78	72	72
1964	110	78	104	86	115	118	106	94	99
1965	142	87	107	100	146	153	140	115	124
1966	147	89	76	79	161	166	147	113	131
1967	154	98	56	72	166	218	174	126	150
1968	168	109	36	62	209	315	196	138	180
1969	307	162	49	81	318	612	326	214	290
1970	383	179	51	81	348	729	430	248	344
1971	405	200	56	101	387	802	375	264	354
1972	468	235	44	103	415	910	422	291	397
1973	569	276	47	116	507	1 162	514	345	482
1974	636	315	53	121	561	1 259	573	378	537
1975	678	328	51	120	590	1 339	581	388	559
1976	673	330	51	110	531	1 229	472	356	510
1977	780	349	49	123	621	1 448	469	384	556
1978	780	355	42	123	619	979	621	379	549
1979	854	373	51	131	603	1 434	716	437	623
1980	1 127	509	56	166	715	1 348	979	552	778
1981	1 245	526	64	171	728	1 901	1 184	635	894

CRO = Composite Revenue Output
CLI = Composite Labour Input
NA = Number of Aircraft
AH = Number of Aircraft Hours (revenue and non-revenue)
ATH = Number of Aircraft Ton-hours (revenue and non-revenue)
FBTU = Fuel in British Thermal Units
MAT = Purchases of Materials, Other than Fuel, and Services (in constant 1971 dollars)
TFI I = Total Factor Inputs Using Aircraft Hours as measure of Capital
TFI II = Total Factor Inputs Using Aircraft Ton-hours as measure of Capital

Source: Aviation Statistics Centre.

Table A.4.4

OUTPUTS AND INPUTS, INDICES, TRANSAIR, 1960-1981
(1960=100)

Year	CRO	CLI	NA	AH	ATH	FBTU	MAT	TFI I	TFI II
1960	100	100	100	100	100	100	100	100	100
1961	129	124	103	121	181	182	159	143	159
1962	163	151	83	140	232	230	200	175	199
1963	169	168	90	159	262	287	215	198	225
1964	152	153	86	145	232	264	189	178	201
1965	152	153	79	148	240	298	152	171	193
1966	165	175	72	147	285	339	260	223	258
1967	157	168	41	116	254	276	229	200	230
1968	184	180	45	117	271	325	243	216	250
1969	254	214	41	153	349	463	359	293	338
1970	342	195	52	139	357	582	331	282	331
1971	402	196	34	118	349	638	467	309	377
1972	405	215	38	111	337	837	369	296	364
1973	545	303	45	134	439	1 226	472	388	488
1974	618	326	31	128	521	1 462	567	425	568
1975	563	319	38	124	504	1 413	586	421	563
1976	715	348	28	137	599	1 652	598	458	620
1977	728	350	24	136	497	1 539	575	446	584
1978	810	348	24	151	546	1 708	627	476	622
1979	617	362	24	114	473	1 441	476	405	539
1980	-	-	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-	-	-

CRO = Composite Revenue Output
CLI = Composite Labour Input
NA = Number of Aircraft
AH = Number of Aircraft Hours (revenue and non-revenue)
ATH = Number of Aircraft Ton-hours (revenue and non-revenue)
FBTU = Fuel in British Thermal Units
MAT = Purchases of Materials, Other than Fuel, and Services (in constant 1971 dollars)
TFI I = Total Factor Inputs Using Aircraft Hours as measure of Capital
TFI II = Total Factor Inputs Using Aircraft Ton-hours as measure of Capital

Source: Aviation Statistics Centre.

Table A.4.5

OUTPUTS AND INPUTS, INDICES, NORDAIR, 1960-1981
(1960=100)

Year	CRO	CLI	NA	AH	ATH	FBTU	MAT	TFI I	TFI II
1960	100	100	100	100	100	100	100	100	100
1961	116	130	90	132	119	120	124	127	124
1962	94	116	67	99	83	94	92	100	96
1963	82	95	95	80	68	69	69	78	75
1964	94	106	95	89	89	90	84	92	92
1965	106	121	95	96	117	125	118	115	120
1966	116	140	95	94	131	135	124	122	132
1967	101	151	95	80	115	117	108	112	122
1968	104	129	52	72	119	163	104	110	123
1969	195	145	43	86	126	251	149	141	154
1970	216	189	62	91	143	311	177	168	186
1971	301	209	86	120	174	401	227	209	227
1972	354	277	114	151	220	514	292	269	292
1973	381	348	95	172	278	653	345	323	361
1974	417	412	90	171	303	734	436	371	424
1975	431	436	95	169	326	833	504	404	470
1976	496	437	71	164	362	1 057	550	436	520
1977	514	409	62	143	352	1 018	564	416	508
1978	536	424	67	148	366	1 038	568	426	520
1979	817	556	76	194	540	1 447	882	599	748
1980	809	780	76	192	446	1 332	831	621	752
1981	776	625	86	179	395	1 264	831	573	688

CRO = Composite Revenue Output
CLI = Composite Labour Input
NA = Number of Aircraft
AH = Number of Aircraft Hours (revenue and non-revenue)
ATH = Number of Aircraft Ton-hours (revenue and non-revenue)
FBTU = Fuel in British Thermal Units
MAT = Purchases of Materials, Other than Fuel, and Services (in constant 1971 dollars)
TFI I = Total Factor Inputs Using Aircraft Hours as measure of Capital
TFI II = Total Factor Inputs Using Aircraft Ton-hours as measure of Capital

Source: Aviation Statistics Centre.

Table A.4.6

OUTPUTS AND INPUTS, INDICES, QUEBECAIR, 1960-1981
(1960=100)

Year	CRO	CLI	NA	AH	ATH	FBTU	MAT	TFI I	TFI II
1960	100	100	100	100	100	100	100	100	100
1961	91	114	100	71	84	97	98	99	101
1962	102	102	89	85	89	99	80	91	91
1963	104	98	100	85	88	96	89	93	93
1964	101	101	100	87	89	100	87	94	94
1965	108	108	144	94	97	105	95	101	101
1966	136	136	156	122	127	137	119	128	128
1967	150	136	122	129	133	144	95	121	121
1968	165	148	156	159	150	195	117	143	141
1969	228	154	111	143	187	367	165	176	179
1970	235	153	89	125	180	329	156	167	172
1971	303	164	222	160	233	350	184	190	196
1972	337	166	67	167	241	359	184	193	199
1973	422	177	78	181	295	466	212	217	231
1974	489	237	111	208	393	582	279	274	305
1975	740	324	111	271	789	1 151	510	434	529
1976	725	322	111	267	748	1 071	515	425	516
1977	946	359	111	334	975	1 378	629	514	628
1978	990	366	100	356	1 066	1 392	751	552	679
1979	896	362	67	337	902	1 194	655	506	609
1980	732	293	89	256	557	707	508	374	432
1981	780	276	244	233	616	797	612	392	470

CRO = Composite Revenue Output
CLI = Composite Labour Input
NA = Number of Aircraft
AH = Number of Aircraft Hours (revenue and non-revenue)
ATH = Number of Aircraft Ton-hours (revenue and non-revenue)
FBTU = Fuel in British Thermal Units
MAT = Purchases of Materials, Other than Fuel, and Services (in constant 1971 dollars)
TFI I = Total Factor Inputs Using Aircraft Hours as measure of Capital
TFI II = Total Factor Inputs Using Aircraft Ton-hours as measure of Capital

Source: Aviation Statistics Centre.

Table A.4.7

OUTPUTS AND INPUTS, INDICES, EPA, 1960-1981
(1960=100)

Year	CRO	CLI	NA	AH	ATH	FBTU	MAT	TFI I	TFI II
1960	100	100	100	100	100	100	100	100	100
1961	112	120	100	112	106	117	127	120	119
1962	116	138	112	116	123	117	136	129	130
1963	103	141	109	115	107	125	140	132	131
1964	114	151	79	113	114	135	153	142	141
1965	102	159	91	104	108	128	107	124	124
1966	120	163	97	121	108	125	135	138	135
1967	132	178	100	136	118	137	157	155	151
1968	139	188	103	124	133	152	174	165	165
1969	179	198	94	127	165	256	208	193	197
1970	251	190	74	106	182	375	269	218	229
1971	288	181	32	79	204	419	321	224	251
1972	328	179	32	84	231	495	323	232	263
1973	409	207	35	90	278	642	368	267	310
1974	469	244	29	98	331	925	444	324	383
1975	486	286	32	93	343	834	446	330	394
1976	469	285	26	87	335	811	444	325	390
1977	514	284	26	88	335	822	478	335	401
1978	590	299	26	94	359	867	493	351	421
1979	627	297	26	93	367	893	581	373	449
1980	654	301	26	101	388	915	778	428	514
1981	730	308	29	107	387	892	1 101	512	616

CRO = Composite Revenue Output
CLI = Composite Labour Input
NA = Number of Aircraft
AH = Number of Aircraft Hours (revenue and non-revenue)
ATH = Number of Aircraft Ton-hours (revenue and non-revenue)
FBTU = Fuel in British Thermal Units
MAT = Purchases of Materials, Other than Fuel, and Services (in constant 1971 dollars)
TFI I = Total Factor Inputs Using Aircraft Hours as measure of Capital
TFI II = Total Factor Inputs Using Aircraft Ton-hours as measure of Capital

Source: Aviation Statistics Centre.

Table A.5.1

LABOUR PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN PASSENGER-MILES, BY AIRLINE, 1960-1981

	ASM per Employee		RPM per Employee						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	278	332	183	197	52	79	37	113	49
1961	328	413	212	217	68	72	43	92	58
1962	367	546	223	293	74	68	57	120	63
1963	396	633	250	323	84	66	44	124	48
1964	399	621	270	374	189	110	113	120	76
1965	445	655	303	408	214	118	200	121	56
1966	466	678	316	401	234	160	187	124	64
1967	509	689	337	392	255	135	133	138	64
1968	579	760	341	384	321	158	264	141	73
1969	613	819	367	458	371	167	318	189	112
1970	659	874	405	503	430	287	286	216	212
1971	682	828	409	491	347	349	429	291	292
1972	696	802	488	534	318	353	458	337	331
1973	754	820	541	544	342	366	392	396	378
1974	773	893	515	555	321	521	429	389	419
1975	845	941	537	580	312	429	482	665	395
1976	866	951	551	631	357	575	664	624	404
1977	895	999	565	721	450	517	817	747	413
1978	973	996	598	773	452	592	791	771	436
1979	1 007	984	662	791	407	433	910	612	467
1980	951	816	657	653	392	-	514	436	450
1981	979	991	619	774	418	-	623	535	496

ASM: available seat-miles
RPM: revenue passenger-miles

Source: Aviation Statistics Centre.

Table A.5.2

LABOUR PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN GOODS TON-MILES, BY AIRLINE, 1960-1981

	ATM per Employee		RTM* per Employee						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	35 803	41 195	21 277	22 452					
1961	44 248	53 272	24 265	24 588					
1962	49 408	70 979	25 993	32 657					
1963	54 145	83 171	29 361	36 690					
1964	57 638	80 755	32 413	43 259	25 771	26 852	28 863	13 878	13 193
1965	68 170	95 371	36 916	47 693	30 450	26 877	39 226	14 045	11 055
1966	71 673	89 925	38 854	48 305	32 700	25 187	39 943	14 440	12 591
1967	75 988	100 380	40 944	47 620	35 256	23 173	29 220	15 741	12 145
1968	87 659	109 634	43 295	48 276	46 715	24 968	43 235	17 645	12 887
1969	97 673	113 682	48 100	56 326	55 853	27 976	57 230	25 867	16 904
1970	109 853	120 499	53 400	60 460	62 751	40 052	52 109	24 851	27 579
1971	115 811	112 470	55 666	60 465	56 294	45 833	74 452	32 334	35 931
1972	117 836	110 240	65 078	65 199	53 100	45 053	71 893	37 453	40 289
1973	127 230	115 673	70 411	66 061	61 252	46 502	56 996	44 662	44 120
1974	129 107	128 407	66 013	68 444	61 099	60 019	56 304	46 742	47 461
1975	139 593	132 452	68 443	72 275	60 251	49 164	61 889	74 556	44 195
1976	148 119	134 339	71 186	79 600	52 987	64 388	80 898	70 159	45 278
1977	148 619	140 192	72 186	87 720	61 598	57 942	99 624	85 026	45 942
1978	157 701	138 822	76 676	94 234	57 991	66 673	96 159	86 066	49 126
1979	165 363	137 342	83 441	94 762	54 190	48 924	104 560	67 860	52 545
1980	153 848	113 948	81 892	78 748	49 097	-	61 418	46 299	50 188
1981	157 009	139 306	78 314	85 536	37 641	-	43 499	18 631	52 711

ATM: available ton-miles
RTM: revenue ton-miles

* RTM including bulk output not available before 1964 for regional carriers.

Source: Aviation Statistics Centre.

Table A.5.3

LABOUR PRODUCTIVITY WITH RESPECT TO MEASURES OF AVAILABLE AND REVENUE OUTPUTS, BY AIRLINE, 1960-1981

(1960=100)

	CAO* per CLI		CRO** per CLI						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	100	100	100	100	100	100	100	100	100
1961	119	123	113	109	110	104	90	80	94
1962	128	163	115	145	114	108	81	101	84
1963	142	182	128	158	136	100	86	106	73
1964	150	179	139	175	141	99	88	100	75
1965	168	185	157	194	164	100	87	100	64
1966	168	183	159	198	165	94	83	101	74
1967	177	182	167	197	157	93	67	110	74
1968	198	199	170	199	154	102	80	111	74
1969	216	228	184	231	190	119	135	148	90
1970	241	242	202	252	213	175	114	154	132
1971	248	228	206	252	202	205	144	185	160
1972	252	220	235	277	199	189	128	204	183
1973	271	226	257	277	206	180	110	239	198
1974	275	243	248	292	202	190	101	207	192
1975	298	258	248	304	206	177	99	228	170
1976	297	267	253	327	204	205	113	225	165
1977	303	283	266	357	224	208	126	263	181
1978	333	281	278	383	220	232	126	270	197
1979	337	279	299	386	229	178	147	248	211
1980	323	234	293	324	221	-	104	250	217
1981	319	279	286	379	237	-	124	282	237

* CAO is a composite measure of available output based on available seat-miles and available goods ton-miles.

** CRO is a composite measure of revenue output based on revenue passenger-miles and revenue goods ton-miles.

Source: Aviation Statistics Centre.

Table A.6.1

CAPITAL PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN PASSENGER-MILES, BY AIRLINE, 1960-1981

	ASM per Aircraft Hour		RPM per Aircraft Hour						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	11 718	18 205	7 708	10 802	745	1 012	416	2 391	528
1961	18 504	22 352	11 928	11 758	864	960	473	3 245	688
1962	22 928	29 484	13 924	15 817	1 059	960	744	3 075	828
1963	25 202	34 096	15 891	17 396	1 099	913	599	3 104	654
1964	25 232	37 193	17 084	22 375	2 424	1 489	1 546	3 078	1 120
1965	26 498	38 271	18 026	23 853	2 571	1 599	2 839	2 992	1 035
1966	26 839	40 760	18 188	24 151	3 847	2 484	3 124	2 841	1 022
1967	27 490	42 966	18 224	24 461	5 032	2 585	2 892	3 180	958
1968	31 547	49 558	18 582	25 029	8 352	3 215	5 338	2 781	1 265
1969	35 042	54 890	20 972	30 713	11 300	3 008	6 200	4 293	2 017
1970	38 079	56 510	23 390	32 515	15 205	5 147	6 940	5 580	4 471
1971	40 898	55 030	24 496	32 651	10 480	7 267	8 515	6 433	7 872
1972	42 664	53 398	29 902	35 571	10 948	9 004	9 125	7 193	8 499
1973	46 675	54 216	33 487	35 937	12 126	10 567	8 662	8 322	10 778
1974	51 331	63 123	34 244	39 217	12 643	16 982	11 623	9 537	12 903
1975	53 752	70 330	34 131	43 373	13 311	14 389	13 698	17 148	14 983
1976	55 708	70 504	35 426	46 758	16 697	19 214	19 500	15 590	15 902
1977	59 545	74 440	37 612	53 710	19 805	17 366	15 900	16 878	16 245
1978	63 188	75 663	38 853	58 732	20 323	17 419	25 005	17 402	17 335
1979	63 135	73 764	41 481	59 273	18 429	16 818	28 404	14 270	18 431
1980	60 780	76 086	41 996	69 895	18 751	-	23 614	11 572	16 556
1981	64 355	78 929	40 654	61 616	20 448	-	23 842	16 625	17 646

ASM: available seat-miles
RPM: revenue passenger-miles

Source: Aviation Statistics Centre.

Table A.6.2

CAPITAL PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN GOODS TON-MILES, BY AIRLINE, 1960-1981

	ATM per Aircraft Hour		RTM* per Aircraft Hour						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	1 505	2 261	894	1 232					
1961	2 492	2 878	1 367	1 328					
1962	3 091	3 820	1 626	1 758					
1963	3 454	4 494	1 873	1 982					
1964	3 651	4 887	2 053	2 618	327	369	401	355	196
1965	4 045	5 557	2 191	2 779	366	362	551	352	199
1966	4 123	5 392	2 235	2 896	531	389	675	342	198
1967	4 100	6 247	2 209	2 964	701	439	629	355	182
1968	4 772	7 132	2 357	3 140	1 201	500	893	346	220
1969	5 576	7 637	2 746	3 784	1 679	503	1 101	583	305
1970	6 357	7 769	3 090	3 898	2 194	726	1 244	646	584
1971	6 935	7 436	3 333	3 998	1 684	981	1 498	705	989
1972	7 220	7 331	3 988	4 336	1 821	1 126	1 457	793	1 045
1973	7 871	7 611	4 355	4 347	2 176	1 348	1 280	939	1 242
1974	8 569	9 069	4 381	4 834	2 397	1 950	1 507	1 132	1 458
1975	8 869	9 888	4 349	5 395	2 545	1 608	1 763	1 902	1 685
1976	9 533	9 934	4 581	5 886	2 465	2 109	2 377	1 765	1 821
1977	9 890	10 446	4 804	6 536	2 710	1 948	3 158	1 921	1 809
1978	10 243	10 546	4 980	7 159	2 607	1 961	3 039	1 943	1 954
1979	10 365	10 298	5 230	7 105	2 454	1 900	3 264	1 583	2 076
1980	9 828	10 620	5 231	7 339	2 347	-	2 824	1 228	1 847
1981	10 330	11 088	5 147	6 812	1 841	-	1 664	579	1 876

ATM: available ton-miles
RTM: revenue ton-miles

* RTM including bulk output not available before 1964 for regional carriers.

Source: Aviation Statistics Centre.

Table A.6.3

CAPITAL PRODUCTIVITY WITH RESPECT TO MEASURES OF AVAILABLE AND REVENUE OUTPUTS, BY AIRLINE, 1960-1981

(1960=100)

Year	CAO* per Aircraft Hour		CRO** per Aircraft Hour						
	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	100	100	100	100	100	100	100	100	100
1961	159	121	151	108	99	107	88	129	101
1962	199	163	179	144	116	116	95	120	100
1963	224	185	202	160	123	107	103	123	90
1964	235	202	218	198	129	104	106	117	101
1965	245	201	230	212	142	103	110	115	98
1966	240	206	227	222	187	112	124	112	99
1967	237	211	223	229	213	135	127	116	97
1968	268	242	231	241	270	157	143	104	112
1969	303	280	259	284	380	166	228	159	141
1970	342	284	287	296	474	246	237	187	237
1971	364	274	301	303	399	341	251	189	364
1972	377	267	351	336	454	366	235	202	391
1973	409	273	387	335	490	408	222	233	453
1974	441	314	398	376	524	483	244	236	479
1975	461	352	384	415	566	453	255	273	524
1976	474	362	403	443	611	523	303	272	538
1977	499	385	438	487	633	533	358	283	581
1978	535	390	446	533	635	536	361	278	626
1979	526	384	466	531	652	541	420	266	671
1980	515	394	467	544	680	-	421	285	645
1981	526	406	472	552	729	-	433	334	680

* CAO is a composite measure of available output based on available seat-miles and available goods ton-miles.

** CRO is a composite measure of revenue output based on revenue passenger-miles and revenue goods ton-miles.

Source: Aviation Statistics Centre.

Table A.6.4

CAPITAL PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN PASSENGER-MILES, BY AIRLINE, 1960-1981

	ASM per Aircraft Ton-hour		RPM per Aircraft Ton-hour						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	310	298	204	177	58	94	19	164	44
1961	372	321	239	169	79	59	24	183	58
1962	401	361	244	194	93	53	41	200	63
1963	393	377	248	193	85	51	32	203	57
1964	382	379	259	228	139	86	71	200	92
1965	386	389	263	243	138	89	105	195	80
1966	389	406	263	241	145	117	103	188	92
1967	412	431	273	245	173	107	91	200	90
1968	442	447	260	226	193	124	152	195	96
1969	449	486	269	272	222	121	190	218	127
1970	432	506	266	291	272	184	199	261	213
1971	441	506	264	300	213	231	270	290	254
1972	438	503	307	335	211	264	289	329	255
1973	453	506	325	335	217	294	248	341	281
1974	476	499	318	310	213	379	295	331	310
1975	487	505	309	312	209	315	323	388	332
1976	498	497	317	329	269	392	402	372	345
1977	514	501	324	362	307	427	478	382	352
1978	538	503	331	391	316	445	460	386	368
1979	530	499	348	401	311	372	468	357	383
1980	534	512	369	410	341	-	459	349	354
1981	566	531	358	414	375	-	494	425	394

ASM: available seat-miles
RPM: revenue passenger-miles

Source: Aviation Statistics Centre.

Table A.6.5

CAPITAL PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN GOODS TON-MILES, BY AIRLINE, 1960-1981

	ATM per Aircraft Ton-hour		RTM* per Aircraft Ton-hour						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	40	37	23.7	20.1					
1961	50	41	27.5	19.1					
1962	54	47	28.4	21.6					
1963	54	50	29.1	21.9					
1964	55	49	31.0	26.4	18.95	20.96	18.17	23.02	15.91
1965	59	57	32.0	28.3	19.65	20.23	20.60	22.66	15.59
1966	60	54	32.4	29.0	20.24	18.32	21.96	21.94	18.06
1967	62	63	33.2	29.8	23.84	18.32	19.91	22.85	17.20
1968	67	64	33.0	28.4	28.08	19.64	24.82	24.48	16.80
1969	73	68	35.2	33.5	33.39	20.12	34.20	29.76	19.12
1970	72	70	35.1	35.0	39.74	25.77	36.20	29.97	27.72
1971	75	69	36.0	36.9	34.48	30.29	46.93	32.22	31.26
1972	74	69	40.9	40.9	35.35	33.75	45.40	36.52	30.97
1973	76	71	42.3	40.7	38.94	37.42	36.05	38.47	32.84
1974	80	72	40.7	38.3	40.47	43.71	38.74	39.83	35.14
1975	80	71	39.4	38.8	40.35	36.13	41.49	43.52	37.20
1976	85	70	41.0	41.6	39.91	43.91	48.97	41.88	38.64
1977	85	70	41.4	44.0	42.01	47.90	58.29	43.48	39.07
1978	87	70	42.4	47.6	40.57	50.13	55.88	43.08	41.45
1979	87	70	43.9	48.1	41.38	42.01	53.75	39.64	43.08
1980	86	71	46.0	49.4	42.73	-	54.83	37.08	39.46
1981	91	75	45.3	45.8	33.80	-	34.49	14.82	41.85

ATM: available ton-miles
RTM: revenue ton-miles

* RTM including bulk output not available before 1964 for regional carriers.

Source: Aviation Statistics Centre.

Table A.6.6

CAPITAL PRODUCTIVITY WITH RESPECT TO MEASURES OF AVAILABLE AND REVENUE OUTPUTS, BY AIRLINE, 1960-1981

(1960=100)

	CAO* per Aircraft Ton-hour		CRO** per Aircraft Ton-hour						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	100	100	100	100	100	100	100	100	100
1961	121	107	115	95	114	71	98	109	106
1962	131	122	118	108	129	70	113	115	94
1963	132	125	118	108	124	65	120	118	97
1964	134	125	124	122	96	65	105	114	100
1965	135	126	127	132	97	63	90	111	94
1966	131	126	124	136	91	58	89	108	111
1967	134	130	127	141	93	62	88	113	113
1968	142	134	122	134	81	68	87	110	105
1969	147	152	125	154	97	73	156	122	108
1970	146	157	123	163	110	96	151	130	138
1971	148	155	123	172	105	115	173	130	141
1972	146	154	136	194	113	120	161	140	142
1973	150	157	142	193	112	124	137	143	147
1974	155	153	140	183	113	119	138	125	142
1975	158	155	131	183	115	112	132	94	142
1976	160	157	136	192	127	120	137	97	140
1977	163	159	143	202	126	146	146	97	153
1978	172	159	143	217	126	148	146	93	164
1979	167	159	148	220	142	130	151	99	171
1980	171	162	155	224	158	-	182	131	169
1981	174	168	156	228	171	-	197	127	188

* CAO is a composite measure of available output based on available seat-miles and available goods ton-miles.

** CRO is a composite measure of revenue output based on revenue passenger-miles and revenue goods ton-miles.

Source: Aviation Statistics Centre.

Table A.7.1

MATERIAL PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN PASSENGER-MILES, BY AIRLINE, 1960-1981

	ASM per Constant Dollar of Material Costs		RPM per Constant Dollar of Material Costs						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	51	42	33	25	9	14	4	18	7
1961	58	49	37	26	12	10	5	17	7
1962	62	53	37	28	13	9	7	24	8
1963	59	57	37	29	13	9	6	22	6
1964	54	57	36	34	24	16	15	22	10
1965	54	53	36	33	23	21	21	22	12
1966	54	58	36	35	26	19	22	22	11
1967	61	61	40	35	27	18	19	30	10
1968	73	73	43	37	33	21	34	27	11
1969	75	75	45	42	35	17	32	27	15
1970	72	77	44	44	36	30	32	33	21
1971	77	81	46	48	35	26	41	40	24
1972	74	78	52	52	34	36	43	47	27
1973	77	81	55	54	35	41	39	52	32
1974	81	89	54	55	34	52	41	51	34
1975	92	92	59	57	34	40	41	65	38
1976	89	89	57	59	49	58	52	59	39
1977	91	88	58	63	66	55	59	64	37
1978	88	81	54	63	51	58	59	60	40
1979	85	77	56	62	42	55	57	53	36
1980	78	79	54	63	40	-	49	42	26
1981	77	81	49	63	37	-	46	46	21

ASM: available seat-miles
RPM: revenue passenger-miles

Source: Aviation Statistics Centre.

Table A.7.2

MATERIAL PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN GOODS TON-MILES, BY AIRLINE, 1960-1981

	ATM per Constant Dollar of Material Costs		RTM* per Constant Dollar of Material Costs						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	6.52	5.25	3.88	2.86					
1961	7.80	6.37	4.28	2.94					
1962	8.27	6.86	4.35	3.16					
1963	8.12	7.47	4.40	3.29					
1964	7.78	7.42	4.37	3.97	3.33	3.84	3.82	2.56	1.76
1965	8.20	7.73	4.44	3.87	3.30	4.76	4.04	2.51	2.33
1966	8.29	7.73	4.49	4.15	3.57	2.98	4.61	2.55	2.14
1967	9.09	8.84	4.90	4.19	3.68	3.02	4.19	3.48	1.92
1968	10.98	10.49	5.43	4.62	4.81	3.26	5.61	3.39	1.91
1969	11.92	10.39	5.87	5.15	5.26	2.90	5.71	3.65	2.25
1970	12.07	10.64	5.87	5.34	5.20	4.13	5.78	3.75	2.78
1971	13.08	10.95	6.28	5.89	5.74	3.36	7.12	4.42	2.95
1972	12.45	10.67	6.88	6.31	5.62	4.58	6.77	5.22	3.29
1973	12.97	11.45	7.18	6.54	6.21	5.18	5.73	5.81	3.69
1974	13.56	12.82	6.94	6.83	6.40	5.97	5.31	6.09	3.89
1975	15.23	12.91	7.47	7.05	6.61	4.62	5.31	7.33	4.25
1976	15.23	12.52	7.32	7.42	7.25	6.54	6.37	6.61	4.32
1977	15.17	12.31	7.37	7.71	8.97	6.15	7.20	7.33	4.08
1978	14.31	11.35	6.96	7.71	6.53	6.49	7.13	6.65	4.48
1979	14.02	10.82	7.08	7.46	5.62	6.22	6.51	5.93	4.04
1980	12.64	10.96	6.73	7.57	5.40	-	5.82	4.41	2.93
1981	12.39	11.32	6.18	6.95	3.35	-	3.24	1.62	2.19

ATM: available ton-miles
RTM: revenue ton-miles

* RTM including bulk output not available before 1964 for regional carriers.

Source: Aviation Statistics Centre.

Table A.7.3

MATERIAL PRODUCTIVITY WITH RESPECT TO MEASURES OF AVAILABLE AND REVENUE OUTPUTS, BY AIRLINE, 1960-1981

(1960=100)

	CAO* per Constant Dollar of Material Costs		CRO** per Constant Dollar of Material Costs						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	100	100	100	100	100	100	100	100	100
1961	115	115	109	103	105	81	94	93	88
1962	123	126	110	111	112	81	102	128	85
1963	122	133	109	115	113	79	118	117	74
1964	115	132	107	129	104	80	112	116	74
1965	115	121	108	127	101	100	89	113	95
1966	111	127	105	137	100	63	94	115	89
1967	121	129	114	139	89	68	94	158	85
1968	143	153	123	153	86	76	100	140	80
1969	149	164	128	166	94	71	131	138	86
1970	150	168	126	175	89	103	122	150	93
1971	158	174	131	192	108	86	133	164	90
1972	150	167	140	211	111	110	121	184	102
1973	156	177	148	217	111	116	110	199	111
1974	159	190	144	227	111	109	96	175	106
1975	182	198	152	233	117	96	85	145	109
1976	175	196	149	240	143	120	90	141	105
1977	177	196	155	248	166	127	91	151	107
1978	173	181	144	247	126	129	94	132	120
1979	164	173	145	239	119	130	93	137	108
1980	153	174	139	241	115	-	97	144	84
1981	145	179	131	243	105	-	93	127	66

* CAO is a composite measure of available output based on available seat-miles and available goods ton-miles.

** CRO is a composite measure of revenue output based on revenue passenger-miles and revenue goods ton-miles.

Source: Aviation Statistics Centre.

Table A.8.1

FUEL PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN PASSENGER-MILES, BY AIRLINE, 1960-1981

	ASM per Million BTU of Fuel		RPM per Million BTU of Fuel						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	223	270	147	160	72	114	24	115	45
1961	211	238	136	125	99	70	30	111	54
1962	224	239	136	128	110	65	46	127	68
1963	221	241	139	124	100	56	40	131	50
1964	213	232	144	140	167	91	89	124	80
1965	217	240	148	149	163	87	125	126	69
1966	216	245	146	145	173	119	127	122	81
1967	226	254	150	145	163	119	114	130	79
1968	242	287	143	145	158	125	140	105	85
1969	247	280	148	157	143	110	121	78	84
1970	247	283	152	163	161	137	116	100	106
1971	249	304	149	181	127	152	149	135	127
1972	246	273	172	182	120	129	157	155	122
1973	256	276	184	183	118	127	134	151	125
1974	272	304	181	189	118	164	155	157	114
1975	290	319	184	197	114	136	161	187	140
1976	302	319	192	211	144	172	175	182	146
1977	319	318	201	229	163	167	210	190	147
1978	345	321	212	249	247	172	206	207	156
1979	341	314	224	253	162	148	222	189	161
1980	338	326	234	261	224	-	195	193	154
1981	357	357	225	279	178	-	196	230	175

ASM: available seat-miles
RPM: revenue passenger-miles

Source: Aviation Statistics Centre.

Table A.8.2

FUEL PRODUCTIVITY WITH RESPECT TO OUTPUT MEASURED IN GOODS TON-MILES, BY AIRLINE, 1960-1981

Year	ATM per Million BTU of Fuel		RTM* per Million BTU of Fuel						
	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	29	33	17.0	18.3					
1961	29	31	15.6	14.2					
1962	30	31	15.8	14.3					
1963	30	32	16.4	14.1					
1964	31	30	17.3	16.2	22.86	22.33	22.70	14.34	13.80
1965	33	35	18.0	17.4	23.20	19.77	24.55	14.69	13.52
1966	33	33	18.0	17.5	24.25	18.61	27.01	14.24	16.00
1967	34	37	18.2	17.6	22.51	20.37	24.96	14.81	15.10
1968	37	41	18.1	18.2	23.01	19.85	22.91	13.16	15.00
1969	39	39	19.3	19.2	21.46	18.34	21.72	10.63	12.63
1970	41	39	20.0	19.6	23.52	19.14	21.07	11.51	13.75
1971	42	41	20.3	22.2	20.58	20.02	25.88	15.02	15.60
1972	42	38	23.0	22.2	19.98	16.45	24.67	17.21	14.79
1973	43	39	23.9	22.2	21.06	16.21	19.44	17.05	14.59
1974	45	44	23.2	23.3	22.35	18.85	20.28	18.86	12.88
1975	48	45	23.5	24.5	22.02	15.60	20.63	20.63	15.68
1976	52	45	24.8	26.7	21.37	19.27	19.27	21.30	16.34
1977	53	45	25.7	27.9	22.32	18.71	25.58	21.58	16.38
1978	56	45	27.2	30.4	31.75	19.40	25.04	23.16	17.57
1979	56	44	28.2	30.3	21.54	16.71	25.48	21.01	18.13
1980	55	46	29.1	31.5	28.05	-	23.30	20.50	17.16
1981	57	50	28.5	30.6	16.04	-	13.68	8.02	18.65

ATM: available ton-miles
RTM: revenue ton-miles

* RTM including bulk output not available before 1964 for regional carriers.

Source: Aviation Statistics Centre.

Table A.8.3

FUEL PRODUCTIVITY WITH RESPECT TO MEASURES OF AVAILABLE AND REVENUE OUTPUTS, BY AIRLINE, 1960-1981
(1960=100)

	CAO* per Fuel in BTU		CRO** per Constant Dollar of Material Costs						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	100	100	100	100	100	100	100	100	100
1961	96	87	91	78	116	71	97	94	96
1962	102	89	91	79	123	71	100	104	99
1963	103	89	93	77	117	59	119	109	83
1964	104	84	96	82	93	57	104	101	85
1965	106	85	99	90	93	51	84	103	80
1966	101	84	96	90	88	49	86	100	96
1967	103	85	97	92	71	57	87	104	96
1968	108	95	93	94	53	57	64	84	91
1969	112	96	96	97	50	55	78	62	70
1970	116	96	98	100	52	59	69	71	67
1971	116	103	97	114	50	63	75	86	69
1972	114	92	106	116	51	48	69	94	66
1973	118	94	112	116	49	44	58	91	64
1974	123	102	111	122	51	42	57	84	51
1975	131	108	109	127	51	40	52	64	58
1976	135	111	115	136	55	43	47	68	58
1977	141	111	123	141	54	47	50	69	62
1978	153	112	128	153	80	47	52	71	68
1979	149	110	132	152	60	43	56	75	70
1980	151	114	137	157	84	-	61	104	72
1981	153	124	137	169	65	-	61	98	82

* CAO is a composite measure of available output based on available seat-miles and available goods ton-miles.

** CRO is a composite measure of revenue output based on revenue passenger-miles and revenue goods ton-miles.

Source: Aviation Statistics Centre.

Table A.9.1

TOTAL FACTOR PRODUCTIVITY USING TYPE I TOTAL FACTOR INPUT, BY AIRLINE, 1960-1981 (1960=100)

	CAO* per Type I Total Factor Input		CRO** per Type I Total Factor Input						
Year	AC	CP	AC	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	100	100	100	100	100	100	100	100	100
1961	121	113	115	101	108	90	92	92	94
1962	134	133	120	118	115	93	94	112	90
1963	142	143	128	123	122	85	105	113	78
1964	144	143	134	140	117	85	102	108	80
1965	151	139	142	146	123	89	92	107	82
1966	149	142	140	153	130	74	95	107	87
1967	156	143	147	155	122	78	90	124	85
1968	176	164	152	164	122	85	95	115	84
1969	190	181	163	183	144	87	138	130	92
1970	204	187	171	194	154	121	128	140	115
1971	213	185	176	205	153	130	144	159	128
1972	212	178	197	224	161	137	132	174	141
1973	225	184	213	226	165	140	118	195	153
1974	232	200	210	240	168	145	113	179	144
1975	253	213	211	250	175	134	107	171	147
1976	252	216	215	265	189	156	114	170	144
1977	259	222	228	281	203	163	123	184	153
1978	274	217	228	296	206	170	126	179	168
1979	269	212	238	293	195	152	136	177	168
1980	259	203	235	281	204	-	130	196	153
1981	256	222	229	302	196	-	135	199	143

* CAO is a composite measure of available output based on available seat-miles and available goods ton-miles.

** CRO is a composite measure of revenue output based on revenue passenger-miles and revenue goods ton-miles.

Type I Total Factor Input: Total Factor Inputs using Aircraft Hours as measure of Capital.

Source: Aviation Statistics Centre.

Table A.9.2

TOTAL FACTOR PRODUCTIVITY USING TYPE II TOTAL FACTOR INPUT, BY AIRLINE, 1960-1981
(1960=100)

	CAO* per Type II Total Factor Input		CRO** per Type II Total Factor Input						
Year	**AC**	**CP**	**AC**	**CP**	**PWA**	**Transair**	**Nordair**	**Quebecair**	**EPA**
1960	100	100	100	100	100	100	100	100	100
1961	115	113	109	100	110	81	94	90	95
1962	124	130	111	115	117	82	98	112	89
1963	128	138	115	119	123	75	109	112	79
1964	129	135	120	133	111	75	102	108	81
1965	135	132	126	139	115	79	88	107	82
1966	132	134	125	145	112	64	88	107	89
1967	139	136	131	147	102	68	83	124	88
1968	155	152	134	152	94	74	84	117	84
1969	164	167	140	170	106	75	127	127	91
1970	172	173	144	180	111	103	116	136	109
1971	177	173	147	191	114	107	133	154	115
1972	175	166	162	209	118	111	121	169	125
1973	183	172	173	211	118	112	105	183	132
1974	187	183	169	219	118	109	98	161	122
1975	203	192	169	226	121	100	92	140	123
1976	202	195	172	238	132	115	95	140	120
1977	206	199	181	252	140	125	101	151	128
1978	218	194	181	264	142	130	103	146	140
1979	213	190	189	262	137	114	109	147	140
1980	207	182	187	251	145	-	108	169	127
1981	204	199	183	270	139	-	113	166	119

* CAO is a composite measure of available output based on available seat-miles and available goods ton-miles.

** CRO is a composite measure of revenue output based on revenue passenger-miles and revenue goods ton-miles.

Type II Total Factor Input: Total Factor Inputs using Aircraft Ton-Hours as measure of Capital.

Source: Aviation Statistics Centre.

Table A.10.1

ABSOLUTE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1960-1981 (EXCEPT FOR TRANSAIR 1960-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	1.4	1.9	2.9	0.3	2.7	1.8	1.9
2. Capital Input							
a. Number of Aircraft	0.3	1.9	-0.4	-1.6	-0.2	0.7	-0.6
b. Rate of Aircraft Utilization	0.0	-1.3	0.8	1.7	0.7	0.0	0.6
c. Aircraft Quality (Size and Speed of Aircraft)	1.0	0.6	1.3	1.7	0.8	0.8	0.6
3. Material Input (Excluding Fuel)	2.4	3.0	3.8	2.5	3.3	2.7	4.7
4. Fuel Input	1.0	1.7	2.5	2.4	2.4	1.7	1.8
5. Errors due to Approximations	0.1	0.2	0.2	1.3	-0.1	0.1	0.0
6. Residual with respect to CRO (R_1)	2.9	4.8	1.6	-4.2	0.6	2.4	0.8
7. Composite Revenue Output (CRO)	9.1	12.8	12.8	4.2	10.3	10.3	9.9
8. Load Factor	0.6	-1.6	-12.8	-4.2	-10.3	-10.3	-9.9
9. Composite Available Output (CAO)	9.7	11.2	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	3.4	3.3	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	5.1	8.5	8.9	3.8	8.2	7.0	7.9
B. Aircraft Utilization and Aircraft Quality (2b+2c)	1.0	-0.7	2.1	3.4	1.6	0.8	1.2

1. Quantity of labour is measured as Composite Labour Input (CLI)
2a. This number includes owned as well as leased aircraft
2b. Utilization rate is defined as number of hours flown per aircraft per year
2c. The quality of aircraft includes characteristics such as size and speed
3. Measured as constant 1961 dollar expenditures on materials and purchased services
4. Measured in BTU
5. Residual includes, as examples, the effects of changes in labour quality, management quality, economies of scale, route structure and fleet structure

Source: Aviation Statistics Centre.

Table A.10.2

PERCENTAGE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1960-1981 (EXCEPT FOR TRANSAIR 1960-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	15.03	15.03	22.79	8.34	25.99	17.67	19.24
2. Capital Input							
a. Number of Aircraft	3.03	14.53	-2.88	-37.24	-1.46	6.93	-5.71
b. Rate of Aircraft Utilization	-0.23	-10.28	6.43	40.81	7.18	-0.37	6.03
c. Aircraft Quality (Size and Speed of Aircraft)	11.51	4.74	10.03	40.11	8.03	7.88	6.33
3. Material Input (Excluding Fuel)	26.44	23.69	30.12	60.69	32.15	26.72	47.31
4. Fuel Input	11.07	13.02	19.35	58.28	23.67	16.56	18.27
5. Errors due to Approximations	1.10	1.58	1.78	30.45	-1.21	0.87	0.17
6. Residual with respect to CRO (R_1)	32.05	37.69	12.38	-101.44	5.66	23.74	8.36
7. Composite Revenue Output (CRO)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
8. Load Factor	6.26	-12.69	-100.00	-100.00	-100.00	-100.00	-100.00
9. Composite Available Output (CAO)	106.26	87.31	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	37.87	25.93	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	55.57	66.27	69.38	90.07	80.34	67.89	79.10
B. Aircraft Utilization and Aircraft Quality (2b+2c)	11.28	-5.54	16.46	80.92	15.21	7.51	12.37

* Percentages in this table are derived from Table A.10.1 by dividing each row by row 7.

Source: Aviation Statistics Centre.

Table A.10.3

ABSOLUTE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1977-1981 (EXCEPT FOR TRANSAIR 1977-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	1.1	2.3	4.2	-5.2	3.1	-1.8	0.6
2. Capital Input							
a. Number of Aircraft	0.7	8.6	1.0	0.0	1.3	4.4	0.2
b. Rate of Aircraft Utilization	-0.1	-8.2	0.2	-2.9	-0.4	-6.1	0.2
c. Aircraft Quality (Size and Speed of Aircraft)	-0.1	0.0	-0.6	2.0	-0.4	-0.4	-0.1
3. Material Input (Excluding Fuel)	3.1	2.9	7.2	-1.0	3.2	-0.2	9.7
4. Fuel Input	0.6	0.8	1.4	-0.3	1.4	-2.9	0.4
5. Errors due to Approximations	-0.1	0.0	-0.8	5.7	-0.2	0.0	0.0
6. Residual with respect to CRO (R_1)	0.3	1.7	-0.2	-30.5	2.9	2.4	-1.8
7. Composite Revenue Output (CRO)	5.5	8.3	12.4	-32.2	10.9	-4.7	9.2
8. Load Factor	-0.5	-1.9	-12.4	32.2	-10.9	4.7	-9.2
9. Composite Available Output (CAO)	4.9	6.4	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	-0.2	0.0	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	5.4	14.7	13.7	-6.6	9.0	-0.5	10.9
B. Aircraft Utilization and Aircraft Quality (2b+2c)	-0.2	-8.2	-0.4	-0.8	-0.9	-6.5	0.1

1. Quantity of labour is measured as Composite Labour Input (CLI)
2a. This number includes owned as well as leased aircraft
2b. Utilization rate is defined as number of hours flown per aircraft per year
2c. The quality of aircraft includes characteristics such as size and speed
3. Measured as constant 1961 dollar expenditures on materials and purchased services
4. Measured in BTU
5. Residual includes, as examples, the effects of changes in labour quality, management quality, economies of scale, route structure and fleet structure

Source: Aviation Statistics Centre.

Table A.10.4

PERCENTAGE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1977-1981 (EXCEPT FOR TRANSAIR 1977-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	20.65	27.47	33.52	16.15	28.71	37.98	6.67
2. Capital Input							
a. Number of Aircraft	12.43	103.90	7.76	0.00	11.97	-92.55	2.11
b. Rate of Aircraft Utilization	-1.76	-98.09	1.90	8.93	-3.86	129.17	1.71
c. Aircraft Quality (Size and Speed of Aircraft)	-1.22	0.02	-5.10	-6.36	-4.01	9.53	-1.02
3. Material Input (Excluding Fuel)	55.78	35.34	58.28	3.26	29.45	4.20	105.59
4. Fuel Input	10.50	10.05	11.26	0.97	13.05	61.76	4.81
5. Errors due to Approximations	-1.48	0.39	-6.16	-17.63	-1.58	0.87	-0.13
6. Residual with respect to CRO (R_1)	5.11	20.91	-1.45	94.69	26.27	-50.96	-19.74
7. Composite Revenue Output (CRO)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
8. Load Factor	-9.85	-22.60	-100.00	-100.00	-100.00	-100.00	-100.00
9. Composite Available Output (CAO)	90.15	77.40	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	-4.38	0.00	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	99.35	176.77	110.82	20.38	83.18	11.38	119.19
B. Aircraft Utilization and Aircraft Quality (2b+2c)	-2.98	-98.07	-3.20	2.56	-7.87	138.70	0.69

* Percentages in this table are derived from Table A.10.3 by dividing each row by row 7.

Source: Aviation Statistics Centre.

Table A.10.5

ABSOLUTE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1960-1968

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	2.2	2.0	0.4	2.7	1.0	2.1	3.2
2. Capital Input							
a. Number of Aircraft	0.4	-0.0	-1.7	-0.9	-1.5	0.7	0.0
b. Rate of Aircraft Utilization	-0.0	0.6	0.9	1.1	0.7	0.0	0.2
c. Aircraft Quality (Size and Speed of Aircraft)	1.7	1.1	2.2	1.1	1.2	-0.1	0.1
3. Material Input (Excluding Fuel)	3.3	4.1	2.9	4.3	0.2	0.7	2.7
4. Fuel Input	1.4	2.3	2.4	3.0	1.1	1.1	0.7
5. Errors due to Approximations	0.4	0.5	0.3	0.4	-0.0	0.0	-0.6
6. Residual with respect to CRO (R_1)	3.7	5.4	-0.8	-3.7	-2.2	2.0	-2.2
7. Composite Revenue Output (CRO)	13.1	15.9	6.7	7.9	0.5	6.5	4.2
8. Load Factor	3.1	0.0	N/A	N/A	N/A	N/A	N/A
9. Composite Available Output (CAO)	15.2	16.0	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	5.6	5.4	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	7.3	8.4	4.1	9.0	0.7	4.5	6.7
B. Aircraft Utilization and Aircraft Quality (2b+2c)	1.7	1.7	3.0	2.2	2.0	-0.1	0.3

1. Quantity of labour is measured as Composite Labour Input (CLI)
2a. This number includes owned as well as leased aircraft
2b. Utilization rate is defined as number of hours flown per aircraft per year
2c. The quality of aircraft includes characteristics such as size and speed
3. Measured as constant 1961 dollar expenditures on materials and purchased services
4. Measured in BTU
5. Residual includes, as examples, the effects of changes in labour quality, management quality, economies of scale, route structure and fleet structure

Source: Aviation Statistics Centre.

Table A.10.6

PERCENTAGE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1960-1968

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	16.73	12.46	5.93	33.67	205.54	32.94	77.11
2. Capital Input							
a. Number of Aircraft	3.03	-0.11	-24.97	-11.47	-311.87	10.52	0.87
b. Rate of Aircraft Utilization	-0.17	3.46	12.89	13.86	152.16	0.46	5.56
c. Aircraft Quality (Size and Speed of Aircraft)	12.90	6.99	32.17	13.63	247.11	-1.42	2.12
3. Material Input (Excluding Fuel)	25.17	25.62	43.78	54.14	32.08	10.27	63.79
4. Fuel Input	10.58	14.52	36.54	37.91	222.11	16.51	17.00
5. Errors due to Approximations	3.31	3.33	5.16	4.85	-6.32	0.08	-15.02
6. Residual with respect to CRO (R_1)	28.45	33.73	-11.49	-46.59	-440.82	30.65	-51.43
7. Composite Revenue Output (CRO)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
8. Load Factor	16.25	0.25	N/A	N/A	N/A	N/A	N/A
9. Composite Available Output (CAO)	116.25	100.25	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	42.94	33.73	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	55.52	52.49	61.27	114.26	147.86	70.23	158.77
B. Aircraft Utilization and Aircraft Quality (2b+2c)	12.73	20.45	45.07	27.48	399.27	-0.96	7.68

* Percentages in this table are derived from Table A.10.5 by dividing each row by row 7.

Source: Aviation Statistics Centre.

Table A.10.7

ABSOLUTE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1968-1981 (EXCEPT FOR TRANSAIR 1968-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	0.9	1.9	4.4	-0.7	3.6	1.7	1.3
2. Capital Input							
a. Number of Aircraft	0.2	3.2	0.9	-1.5	0.9	0.7	-0.9
b. Rate of Aircraft Utilization	0.0	-2.6	0.7	1.4	0.7	-0.1	0.8
c. Aircraft Quality (Size and Speed of Aircraft)	0.7	0.3	0.4	1.5	0.5	1.6	0.9
3. Material Input (Excluding Fuel)	1.9	2.5	4.4	1.7	5.3	3.9	6.1
4. Fuel Input	0.6	1.1	2.5	2.1	3.4	2.1	2.7
5. Errors due to Approximations	0.0	0.1	0.4	2.0	0.0	0.1	0.1
6. Residual with respect to CRO (R_1)	2.4	4.5	3.1	-4.6	2.3	2.7	2.7
7. Composite Revenue Output (CRO)	6.7	11.0	16.7	1.8	16.7	12.7	13.6
8. Load Factor	-0.3	-2.6	-16.7	-1.8	-16.7	-12.7	-13.6
9. Composite Available Output (CAO)	6.4	8.4	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	2.1	2.1	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	3.6	8.6	12.1	1.5	13.1	8.3	9.1
B. Aircraft Utilization and Aircraft Quality (2b+2c)	0.7	-2.3	1.1	2.9	1.3	1.5	1.7

1. Quantity of labour is measured as Composite Labour Input (CLI)
2a. This number includes owned as well as leased aircraft
2b. Utilisation rate is defined as number of hours flown per aircraft per year
2c. The quality of aircraft includes characteristics such as size and speed
3. Measured as constant 1961 dollar expenditures on materials and purchased services
4. Measured in BTU
5. Residual includes, as examples, the effects of changes in labour quality, management quality, economies of scale, route structure and fleet structure

Source: Aviation Statistics Centre.

Table A.10.8

PERCENTAGE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1968-1981 (EXCEPT FOR TRANSAIR 1968-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	13.42	17.13	26.41	-42.06	21.51	13.07	9.23
2. Capital Input							
a. Number of Aircraft	3.09	28.91	5.38	-84.52	5.19	5.23	-6.48
b. Rate of Aircraft Utilisation	-0.31	-23.75	4.26	80.88	4.35	-0.78	5.69
c. Aircraft Quality (Size and Speed of Aircraft)	12.90	2.97	2.33	82.37	3.17	12.70	6.75
3. Material Input (Excluding Fuel)	25.17	22.52	26.18	93.27	31.47	30.48	44.64
4. Fuel Input	10.58	10.14	14.81	119.22	20.22	16.92	19.52
5. Errors due to Approximations	3.31	0.96	2.32	111.30	0.26	0.87	0.66
6. Residual with respect to CRO (R_1)	28.45	41.13	18.31	-260.45	13.82	21.51	19.99
7. Composite Revenue Output (CRO)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
8. Load Factor	16.25	-23.66	-100.00	-100.00	-100.00	-100.00	-100.00
9. Composite Available Output (CAO)	116.25	76.34	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	42.94	19.02	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	53.14	78.69	72.78	85.91	78.40	65.69	66.91
B. Aircraft Utilization and Aircraft Quality (2b+2c)	10.06	-20.77	6.59	163.25	7.52	11.92	12.44

* Percentages in this table are derived from Table A.10.7 by dividing each row by row 7.

Source: Aviation Statistics Centre.

Table A.10.9

ABSOLUTE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1970-1981 (EXCEPT FOR TRANSAIR 1970-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	0.9	1.7	3.6	-1.0	3.2	1.7	1.4
2. Capital Input							
a. Number of Aircraft	0.2	3.7	0.4	-2.6	0.7	2.0	-0.9
b. Rate of Aircraft Utilisation	0.0	-3.3	1.0	1.9	0.7	-0.8	0.9
c. Aircraft Quality (Size and Speed of Aircraft)	0.4	0.3	0.0	1.7	0.7	1.3	0.7
3. Material Input (Excluding Fuel)	1.7	2.0	2.8	1.0	4.6	3.7	5.4
4. Fuel Input	0.5	0.8	1.5	1.5	2.8	1.6	1.6
5. Errors due to Approximations	0.0	0.1	0.0	2.1	-0.1	0.1	0.3
6. Residual with respect to CRO (R_1)	2.2	3.8	2.1	-8.6	-0.2	1.8	0.8
7. Composite Revenue Output (CRO)	6.0	9.1	11.3	-4.0	12.3	11.5	10.2
8. Load Factor	-0.6	-2.6	-11.3	4.0	-12.3	-11.5	-10.2
9. Composite Available Output (CAO)	5.4	6.5	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	1.6	1.3	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	3.3	8.2	8.3	-1.1	11.2	9.1	7.5
B. Aircraft Utilization and Aircraft Quality (2b+2c)	0.5	-3.0	1.0	3.5	1.4	0.5	1.6

1. Quantity of labour is measured as Composite Labour Input (CLI)
2a. This number includes owned as well as leased aircraft
2b. Utilisation rate is defined as number of hours flown per aircraft per year
2c. The quality of aircraft includes characteristics such as size and speed
3. Measured as constant 1961 dollar expenditures on materials and purchased services
4. Measured in BTU
5. Residual includes, as examples, the effects of changes in labour quality, management quality, economies of scale, route structure and fleet structure

Source: Aviation Statistics Centre.

Table A.10.10

PERCENTAGE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1970-1981 (EXCEPT FOR TRANSAIR 1970-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	15.58	19.14	31.71	24.82	25.76	15.18	13.44
2. Capital Input							
a. Number of Aircraft	3.54	40.96	3.64	63.79	5.31	17.41	-8.43
b. Rate of Aircraft Utilisation	0.34	-36.65	8.60	-46.98	5.84	-6.85	8.52
c. Aircraft Quality (Size and Speed of Aircraft)	7.44	3.85	-0.16	-41.23	5.88	10.90	7.24
3. Material Input (Excluding Fuel)	28.42	22.10	24.35	-24.00	37.10	32.16	53.37
4. Fuel Input	7.62	8.52	13.63	-37.05	22.46	14.09	15.45
5. Errors due to Approximations	0.34	0.83	-0.08	-52.77	-0.41	1.23	2.56
6. Residual with respect to CRO (R_1)	36.73	41.25	18.30	213.43	-1.95	15.89	7.85
7. Composite Revenue Output (CRO)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
8. Load Factor	-10.52	-28.71	-100.00	-100.00	-100.00	-100.00	-100.00
9. Composite Available Output (CAO)	89.48	71.29	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	26.04	14.08	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	55.15	90.72	73.33	27.56	90.64	78.84	73.83
B. Aircraft Utilisation and Aircraft Quality (2b+2c)	7.78	-32.80	8.45	-88.22	11.72	4.04	15.76

* Percentages in this table are derived from Table A.10.9 by dividing each row by row 7.

Source: Aviation Statistics Centre.

Table A.10.11

ABSOLUTE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1973-1981 (EXCEPT FOR TRANSAIR 1973-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	0.8	2.0	3.1	-2.7	2.2	1.7	1.5
2. Capital Input							
a. Number of Aircraft	0.4	4.2	0.7	-3.2	-0.2	3.2	-0.2
b. Rate of Aircraft Utilization	-0.1	-3.8	0.2	2.3	0.3	-2.6	0.4
c. Aircraft Quality (Size and Speed of Aircraft)	0.2	0.5	-0.1	1.2	0.7	1.4	0.2
3. Material Input (Excluding Fuel)	1.6	2.8	3.0	0.0	3.6	4.0	5.8
4. Fuel Input	0.2	1.1	1.2	0.4	2.0	1.5	0.9
5. Errors due to Approximations	0.0	0.2	0.1	3.2	-0.2	0.0	0.2
6. Residual with respect to CRO (R_1)	0.7	3.1	2.1	-13.1	0.9	-1.2	-1.3
7. Composite Revenue Output (CRO)	3.9	10.0	10.3	-11.8	9.3	8.0	7.5
8. Load Factor	0.7	-1.4	-10.3	11.8	-9.3	-8.0	-7.5
9. Composite Available Output (CAO)	4.6	8.6	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	1.4	1.8	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	3.1	10.0	8.0	-5.5	7.6	10.4	8.0
B. Aircraft Utilization and Aircraft Quality (2b+2c)	0.1	-3.3	0.1	3.6	1.0	-1.2	0.6

1. Quantity of labour is measured as Composite Labour Input (CLI)
2a. This number includes owned as well as leased aircraft
2b. Utilisation rate is defined as number of hours flown per aircraft per year
2c. The quality of aircraft includes characteristics such as size and speed
3. Measured as constant 1961 dollar expenditures on materials and purchased services
4. Measured in BTU
5. Residual includes, as examples, the effects of changes in labour quality, management quality, economies of scale, route structure and fleet structure

Source: Aviation Statistics Centre.

Table A.10.12

PERCENTAGE CONTRIBUTIONS OF VARIOUS SOURCES OF GROWTH IN COMPOSITE REVENUE OUTPUT, BY AIRLINE, 1973-1981 (EXCEPT FOR TRANSAIR 1973-1979)

Source of Output Growth	Air Canada	CP Air	PWA	Transair	Nordair	Quebecair	EPA
1. Labour Input	21.64	19.71	29.92	23.19	23.48	21.01	20.51
2. Capital Input							
a. Number of Aircraft	9.06	41.81	6.61	26.93	-2.27	40.45	-2.79
b. Rate of Aircraft Utilization	-2.74	-38.28	1.75	-19.78	3.19	-31.98	5.43
c. Aircraft Quality (Size and Speed of Aircraft)	5.70	4.73	-0.57	-10.50	7.41	16.98	2.44
3. Material Input (Excluding Fuel)	42.18	28.31	29.54	-0.24	39.06	49.96	77.38
4. Fuel Input	6.24	10.61	11.40	-3.27	21.20	18.63	11.81
5. Errors due to Approximations	0.03	1.68	1.21	-27.47	-1.97	0.10	2.40
6. Residual with respect to CRO (R_1)	17.90	31.43	20.14	111.14	9.98	-15.16	-17.18
7. Composite Revenue Output (CRO)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
8. Load Factor	18.93	-14.06	-100.00	-100.00	-100.00	-100.00	-100.00
9. Composite Available Output (CAO)	118.93	85.94	N/A	N/A	N/A	N/A	N/A
10. Residual with respect to CAO (R_2)	35.04	18.47	N/A	N/A	N/A	N/A	N/A
A. Input Quantities (1+2a+3+4)	79.11	100.44	77.47	46.61	81.47	130.06	106.91
B. Aircraft Utilization and Aircraft Quality (2b+2c)	2.96	-33.55	1.18	-30.29	10.60	-15.00	7.87

* Percentages in this table are derived from Table A.10.11 by dividing each row by row 7.

Source: Aviation Statistics Centre.

Appendix B

MEASUREMENT OF TOTAL FACTOR PRODUCTIVITY

This Appendix presents a survey of the status of the theoretical knowledge about productivity. The survey describes the methods currently used to measure total factor productivity, giving a special attention to recent developments. It is hoped that the survey is not only for academics and that it will allow the lay reader to judge the meaning and implications of the empirical productivity study of the Canadian airline industry presented in the text. The survey is oriented on basic issues and on the structure of the problems, specifically the ones pertinent to the Canadian airline industry, leaving the readers who are interested in some fine technical points to investigate the more technical literature themselves.

The section has drawn its inspiration mostly from a paper of Diewert (1981).

B.1 Approach 1: Cost and Production Functions

The requirements of the approach are straightforward. One needs data on output produced by period and on actual inputs used during the said period to produce that level of output. Then, assuming a functional form for the production function that corresponds to the technology of the firm's or industry's production process under study, one is left with the task of estimating the parameters characterizing the functional form using an econometric method such as regression analysis.

Once the parameters are estimated, partially differentiating the function with respect to time, allows the measurement of the percentage change in output due to an increment of time, such a change being associated with a measure of technical change.*

The cost functions can also be used to measure productivity. The producer, having to face positive prices for the inputs he uses in a period, should behave in a competitive way with respect to inputs. If he does so, the producer's cost function results from the solution of a constrained cost minimization problem. The cost function is completely determined by the production function and, under certain conditions,* the cost function completely determines the production function. The advantage of the cost function approach over the production function approach is that the first one is defined under a system of equations and has therefore more degrees of freedom in a statistical sense than the production function single equation. The cost function approach however requires the assumption of competitive behaviour of the producer with respect to inputs.

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* It is recommendable to use as an assumption a functional form that provides a second-order approximation to an arbitrary twice-continuously-differentiable production function. Such functional forms are known as 'flexible'.

B.2 Approach 2: Divisia Indexes

The Divisia index is the index that is most frequently suggested in the measurement of total factor productivity. Denny, Fuss and Waverman (1981) refer to it as 'one of the most defensible methods of aggregation for use in productivity analysis'. The conventional Divisia index implies constant returns to scale, marginal cost pricing and a cost-minimizing behaviour. From a more technical point of view, the derivation of the index requires the assumption of the existence of a production function which is linearly homogeneous, concave and non-decreasing in inputs.

The conventionally measured Divisia index of total factor productivity is defined as the ratio of aggregate output to aggregate input. Aggregate output (input) is an index of disaggregated outputs (inputs). The Divisia indexes for aggregate output and input are defined in terms of proportional rates of growth. They are the weighted sum of growth rates, the weights being the components' shares in total value. The proportional rates of growth are defined in terms of instantaneous changes. However, economic data do not come in continuous-time form; they rather come in discrete form. For instance, data are obtainable in many cases at yearly intervals. Therefore, the continuous-time Divisia index formula for the total factor productivity measurement has to be approximated for application to data for discrete points of time.

The most commonly used discrete approximation to the continuous Divisia index is given by the Tornqvist approximation. Diewert (1976) has demonstrated that 'the Tornqvist formula can be used to aggregate quantities consistently, provided that the underlying (production) function is homogeneous'. However, this is not the only approximation that can be used with discrete data. For some, this implies that the Divisia approach will not result in unique estimates of total factor productivity when it is applied to discrete economic data. Referring to the said objection, Diewert (1981) has said that 'this objection is certainly not a fatal one'.

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* The reader interested in the technical details of the regularity conditions can consult Shephard (1970), McFadden (1978) and Diewert (1978). These references explain in details the duality relation between production functions and cost functions.

B.3 Approach 3: Exact Index Numbers

The first two approaches did not require any restriction as to the number of output produced by the firm. Both approaches can be worked out in the single-output context as well as the multiple-output context. In the case of the exact index number approach, one is dealing specifically with multiple-output firms.

The approach assumes that the firm's production possibilities are defined by a set of variable inputs, each of which has a positive price associated with it, by a set of outputs and their corresponding positive prices, and by a set of fixed inputs (e.g., capital stock components) with their positive rental prices. The feasible output and input combinations that a firm can produce and use, defines the firm's production possibilities. The firm's variable cost function results from the actual minimization by the firm of its variable cost. It can be shown that the firm's variable cost function is concave and linearly homogeneous in input prices for given outputs, given fixed inputs, at a given point in time. If the variable cost function is differentiable with respect to the different variable input prices, then these differentials provide the firm's input demand equations. If the variable cost function is also differentiable with respect to the components of outputs and fixed inputs, then the competitive firm's profit maximization problem, because this approach must assume competitive behaviour, can be decomposed into two parts. One involves the minimization of variable costs when outputs to produce are given and capital services are available. Therefore, within the next part, the firm maximizes its profits with respect to the said outputs and capital services.

The firm's variable cost function can be assumed to be a translog variable cost function.* By imposing certain restrictions on some of the translog function parameters, one can ensure that the variable cost function is linearly homogeneous in input prices. By superimposing the assumption that the producer is engaging in profit-maximizing behaviour, the impact of technical change on variable cost can be defined by the percentage change in variable cost at a given point in time, that cannot be explained by changes in inputs or outputs or by changes in variable input prices.

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* The translog variable cost function can provide a second-order approximation to an arbitrary cost function.

This approach to measure changes in total factor productivity is suitable for discrete data as long as the firm's variable cost function is assumed to be of the translog functional form over the relevant range of outputs, and of variable and fixed inputs. In the case of the Divisia approach, an approximation was needed with discrete data. The three approaches presented so far have a point in common: they all involve approximation errors. The exact index number approach has also the disadvantage of requiring an assumption as to the specific functional form of the firm's variable cost fuctions. When the translog functional form is used, this disadvantage is diminished since it is a flexible functional form.

B.4 Approach 4: The Non-Parametric Method for the Measurement of Technical Progress

This approach is computationally more complex than the others presented so far (a linear programming problem having to be solved for each period under study), therefore it will only be briefly presented here. It should be pointed out that it has the advantage of not requiring any restrictive assumptions about the functional form of the firm's production function, and has only to be continuous, nondecreasing and concave.

The measurement of technical progress (total factor productivity) under this approach reposes on the idea that technical regress is not possible (no-technological-regress assumption). Therefore the maximal output produceable during a period by the inputs is equal to or greater than the maximal output that can be produced by the same inputs during a prior period. The approach assumes also that firms produce a maximal amount of output with given inputs (the efficiency hypothesis). Once the production frontier of a set of outputs and inputs has been determined, the first task becomes one of testing whether the set of inputs and outputs for a given period is on or below the frontier of this set and, then, to verify if the true production function for that given period satisfies the additional property of linear homogeneity. From these tests, which yield a sequence of estimated production functions, the approach uses the estimated production functions which have passed the tests to measure the shifts in the firm's production function over time. The approach's objective is thus to determine whether the data for a given firm allow verification of whether total factor productivity has been increasing over time.

Appendix C

THE DIVISIA INDEX OF TOTAL FACTOR PRODUCTIVITY

In order to estimate productivity growth attained by Canadian airlines over the period 1960-1981, a discrete approximation to the Divisia index of total factor productivity was used. A description of the derivation of the measured Divisia index of TFP follows.

Total factor productivity (TFP) has been defined as the ratio of aggregate output (Q) to aggregate input (F). Aggregate output is an index of disaggregated outputs and aggregate input, an index of disaggregated inputs. The Divisia indexes for aggregate output (Q) and for aggregate input (F) are defined in terms of proportional rates of growth ($\dot{Q}$ and $\dot{F}$) as

$$\dot{Q} = \sum_j \frac{P_j Q_j}{R} \dot{Q}_j \qquad (1)$$

and

$$\dot{F} = \sum_i \frac{w_i X_i}{C} \dot{X}_i \qquad (2)$$

where

P_j = price of output j

Q_j = quantity of output j

$\dot{Q}_j$ = proportional rate of growth of output j

$R = \sum_j P_j Q_j$ = total revenue

w_i = price of input i

X_i = quantity of input i

$\dot{X}_i$ = proportional rate of growth of input i

$C = \sum_i w_i X_i$ = total cost

Since the rate of growth of total factor productivity is conventionally defined as the rate of growth of aggregate output minus the rate of growth of aggregate input, then

$$\dot{TFP} = \dot{Q} - \dot{F} = \sum_j \frac{P_j Q_j}{R} \dot{Q}_j - \sum_i \frac{w_i X_i}{C} \dot{X}_i \qquad (3)$$

The formulas (1) to (3) are in terms of instantaneous changes. For yearly data as employed in this study, the most commonly used discrete approximation to the continuous formulas (1) and (2) comes from the Tornqvist approximations:

$$\Delta \ln Q = \ln \frac{Q_t}{Q_{t-1}} = \frac{1}{2} \sum_j (r_{jt} + r_{j,t-1}) \ln \frac{Q_{jt}}{Q_{j,t-1}} \qquad (4)$$

and

$$\Delta \ln F = \ln \frac{F_t}{F_{t-1}} = \frac{1}{2} \sum_i (s_{it} + s_{j,t-1}) \ln \frac{X_{it}}{X_{i,t-1}} \qquad (5)$$

Here Q_{jt} is the quantity of output Q_j produced in period t

$r_{jt} = P_{jt}Q_{jt}/\sum_j P_{jt}Q_{jt}$ i.e., the revenue share of output Q_j in total revenue during period t

X_{it} = the quantity of input X_i used in period t

$s_{it} = w_iX_i/\sum_i w_iX_i$, i.e., the cost share of output X_i in the total cost during period t.

The corresponding discrete approximation to (3) becomes:

$$\Delta TFP = \Delta \ln Q - \Delta \ln F$$

$$= \frac{1}{2}\sum_j (r_{jt} + r_{j,t-1}) \ln \frac{Q_{jt}}{Q_{j,t-1}} - \frac{1}{2}\sum_i (s_{it} + s_{i,t-1}) \ln \frac{X_{it}}{X_{i,t-1}} \qquad (6)$$

For a particular year, the index is set equal to 100.0 and measuring it according to (6) provides estimates of what is called the conventional index of total factor productivity. When it is linked to the theory of production, this conventional index implies constant returns to scale, marginal cost pricing as well as a cost-minimizing behaviour. If the above assumptions were incorrect, the index would require careful interpretation. When market imperfections are present, it is preferable to adjust the conventional Divisia index. In order to understand the adjustments to be made in such cases, it is necessary to develop the links between the measurement of productivity and the theory of production. The single output (Q) case is used here to illustrate this link, this output being produced by inputs $X_i (i = 1,\ldots,n)$.

The production possibilities are given by the production function:

$$Q = f(X_1,\ldots,X_n,t) \qquad (7)$$

The proportional shift in the production function with time is defined as:

$$\dot{A} = (\partial f/\partial t)\ (1/f) \qquad (8)$$

Such a shifting of the production function through time is associated with technical change. It is such technical change that has to be related to the productivity index. In order to arrive at such a relation, the production function is totally differentiated with respect to time which gives:

$$\frac{\partial Q}{\partial t} = \sum_i \frac{\partial f}{\partial X_i} \frac{\partial X_i}{\partial t} + \frac{\partial f}{\partial t} \qquad (9)$$

Dividing (9) by Q and rearranging terms gives the following:

$$\dot{Q} = \sum_i \frac{\partial f}{\partial X_i} \frac{X_i}{Q} \dot{X}_i + \dot{A} \qquad (10)$$

At this stage, an assumption has to be introduced: the firm is assumed to minimize the cost of producing Q. The first order conditions for cost minimization imply that

$$\frac{\partial f}{\partial X_i} = w_i \bigg/ \left(\frac{\partial C}{\partial Q}\right) \qquad (11)$$

where $(\partial C/\partial Q)$ is the marginal cost of production. Substituting (11) in (10) gives:

$$\dot{Q} = \sum_i \frac{w_i X_i}{\partial C/\partial Q \cdot Q} \dot{X}_i + \dot{A} \qquad (12)$$

If the elasticity of cost with respect to output (ε_{CQ}) is defined as

$$\varepsilon_{CQ} = \frac{\partial C}{\partial Q} \frac{Q}{C} \qquad (13)$$

and (13) is substituted in (12), then the expression for the proportionate rate of growth of output becomes:

$$\dot{Q} = \sum_i \varepsilon_{CQ}^{-1} \frac{w_i X_i}{C} \dot{X}_i + \dot{A} \qquad (14)$$

In the single output case, $\dot{Q}$ is identical to the proportionate rate of growth of output in the measurement of total factor productivity. The index of aggregate inputs F defined in (2) is then substituted in (14) to obtain:

$$\dot{A} = \dot{Q} - \varepsilon_{CQ}^{-1} \dot{F} \tag{15}$$

In order to compare the measure of technical change $\dot{A}$ with the total factor productivity measure ($TFP = \dot{Q} - \dot{F}$), (15) is rearranged to yield:

$$\dot{A} = \dot{TFP} + (1 - \varepsilon_{CQ}^{-1}) \dot{F} \tag{16}$$

or

$$\dot{TFP} = \dot{A} + (\varepsilon_{CQ}^{-1} - 1) \dot{F} \tag{17}$$

Since the inverse of the elasticity of cost with respect to output is the scale elasticity then (17) can be interpreted. For instance, if production is subject to constant returns to scale ($\varepsilon_{CQ} = 1$) then:

$$\dot{A} = \dot{TFP} \tag{18}$$

Under constant returns to scale, the total factor productivity growth rate is identical to the rate of technical change. Therefore, if returns to scale are not constant, total factor productivity will not identically measure shifts in the technology. Under the presence of scale effects, conventional total factor productivity estimates do not measure shifts in the production function. It can be demonstrated also that they do not measure shifts in the cost function*.

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* The duality theory between cost and production implies that a cost function exists for any production function, which provides an equivalent description of the technology.

Appendix D

TRENDS IN OUTPUT

Basically, airlines perform three types of services: Scheduled Passenger Services, Scheduled Goods Transport and Charters. This offering sometimes includes specialty flying, a category which encompasses crop dusting, fire-fighting and aerial photography, among other specialized activities.

The two mainline carriers, Air Canada and CP Air, derive the major portion of their revenues from scheduled passenger services. From 1960 to 1981 there was little fluctuation in that share, which ranged between 82 and 88% for Air Canada and 79 and 87% for CP.

The remainder of their revenues stem mostly from the transport of goods, with charter services never representing more than 3.7% of Air Canada revenue. CP Air, by contrast, saw its share of charter revenue rise from 3 to 9% since 1960, reaching a peak in 1980. Several years were exceptions to the rule, such as 1968 when the share of charter flights fell to 0.25%.

Air Canada offered very little specialty service and none at all after 1977. During the years when the airline did operate such flights, their share of revenue was minimal, never more than 1% of total revenue. CP Air never offered specialty services.

PWA, the third largest airline in Canada, underwent a change in production structure between 1960 and 1981. During the sixties, passenger transportation accounted for almost 50% of the carrier's revenue, the other 50% derived from charter flights (30 to 40%) and the transport of goods. After 1970, the share of passenger transportation increased, producing up to 76% of revenues in 1980. During that time revenue from goods traffic dropped to 8%, whereas charter flights generated no more than 15% of revenues.

PWA operated specialty services over two short three-year periods, 1960-1962 and 1972-1974. Those services generated up to 4.5% of total revenue in 1961 but generally remained marginal.

Between 1960 and 1979, Transair specialized primarily in charter operations. Ranking second was scheduled passenger transportation, followed by scheduled goods transport. Transair also operated several specialty services from 1960 to 1965. As of 1967 or so, the share of scheduled passenger transportation overtook that of charter services. The relative share of this category of air service fell to 16% in 1971, which can counter to the 20 to 30% of total revenue generally observed for the service.

Of the three remaining airlines, only Nordair and EPA show similar operating scenarios. The share of revenue generated by scheduled passenger transport marked steady growth since 1960, jumping from 15 to 56% for Nordair and from 26 to 85% for EPA. EPA's growth occurred at the expense of both goods traffic and charter flights. The proportion of goods transport in the total activity of these airlines dropped steadily since 1960. The decline was stronger for EPA than for Nordair: Nordair saw its share of goods transport drop from 17 to 14% over the period 1960-1981, except for 1969 when the service accounted for 27.5% of the carrier's revenue. EPA saw its share plunge from 41 to 11% over the same 22-year period.

With respect to charter flights, the downward trend during the period 1960-1981 was more pronounced at Nordair than at EPA. Nordair recorded a total decline of 39.34% in the share of charter revenue over the study period, while at EPA the relative share of revenue from charter services dropped some 26%, from 29.16% in 1960 to 3.4% in 1981.

Nordair and EPA both offered specialty flying, though on an irregular basis. Nordair, for example, operated no such flights in 1968, 1969, 1971 or 1976. EPA operated none from 1975 to 1980. The share of specialty flying in total revenues was generally higher at Nordair than at EPA, attaining up to 12 to 13% of Nordair revenue between 1973 and 1976.

At Quebecair, the trend of operations changed during the period under review. The scope of scheduled service was eroded by the growth of charter operations. Scheduled passenger transportation dropped from approximately 80% of total revenue in the early sixties to 40% in 1978. Over that time charter service accounted 3% of 1960 revenue and 50% of total revenue in 1981. It should be noted that the exploitation of energy resources at James Bay generated a need for transportation in the region, served by Quebecair. Between 1976 and 1977, annual earnings from charter flights to James Bay soared from $3 million to some $11 million. In 1981, charter earnings totaled $20 448 395, more than half of the total revenue generated by bulk traffic. The strong rise in traffic to the United States also contributed to the increased importance of charter flights, which rose from $5.9 million in 1980 to $15.8 million in 1981. This instability in the output trend should be kept in mind when interpretating productivity results. Any generalization from the results should be avoided since the irregularities in the supply of some services might have caused biases in the measures from which the generalization is derived.

Two other measures of output can be considered in analysing the evolution of Canadian airline output, namely revenue passenger-miles and available seat-miles. The ratio of revenue passenger-miles to available seat-miles gives the load factor, which should be analysed with a certain amount of caution. It would be easy to conclude that when the load factor nears 100%, the aircraft is at full capacity and revenue at its peak. However, since the introduction of reduced fares (see Chapter 1), load factors may have increased but with seat prices running up to 50% lower, passenger revenue may actually decline.

It appears from Figure D.1 that the Air Canada and CP Air load factors adhered to the same pattern until 1975, the CP factor being lower than that of Air Canada. After 1975, the rate of utilization of CP Air services commenced rising fairly rapidly, whereas that of Air Canada declined. In 1981 the CP load factor remained higher than Air Canada's, 0.78% as against 0.63%.

Certain drops in the load factor can be explained by the use of new, larger aircraft in airline operations. A new aircraft should be chosen with the future needs of the demand in mind. With the introduction of Boeing 747's, DC-10's and L-1011's, it was normal to observe a drop in the load factor, as these airliners necessitated major adjustments in carrier operations.

It is not possible to calculate load factors for the other airlines, which are not required to report their available seat-miles data to Statistics Canada.

The measurement of average revenue may be employed to analyse the impact of reduced fares on the rate of utilization. Dividing total earnings by the number of passenger-miles and comparing this against the load factor gives an approximate idea of the significance of reduced-fare seats.

Average revenues in constant dollars for Air Canada and CP Air are given in Table D.2. It is readily observed that the average revenue of CP Air dropped starting in 1975 when the load factor commenced rising (Table D.1). In other words, the aircraft carried more passengers but each passenger generated less revenue in constant dollars. The same phenomenon is observed for Air Canada. For instance, the load factor is seen to have risen from 1978 to 1979, while average revenue fell. Caution should therefore be exercised in analysing the effect of the load factor on an airline's financial position. For one, the introduction of reduced fares, aimed in part at improving aircraft utilization, may have succeeded but not without cost.

The yield (average revenues) in constant dollars shown in Tables D.3 and D.4 were calculated in term of ton-miles. The aim here is to match yield from unit toll services against yield

Table D.1

LOAD FACTORS
Unit Toll Passenger Services

Year	AC	CP
1960	0.66	0.59
1961	0.64	0.53
1962	0.61	0.54
1963	0.63	0.51
1964	0.68	0.60
1965	0.68	0.62
1966	0.68	0.59
1967	0.66	0.57
1968	0.59	0.51
1969	0.60	0.56
1970	0.61	0.57
1971	0.60	0.59
1972	0.70	0.67
1973	0.72	0.66
1974	0.67	0.62
1975	0.63	0.62
1976	0.64	0.66
1977	0.63	0.72
1978	0.61	0.78
1979	0.66	0.80
1980	0.69	0.80
1981	0.63	0.78

Source: Aviation Statistics Centre.

Figure D.1

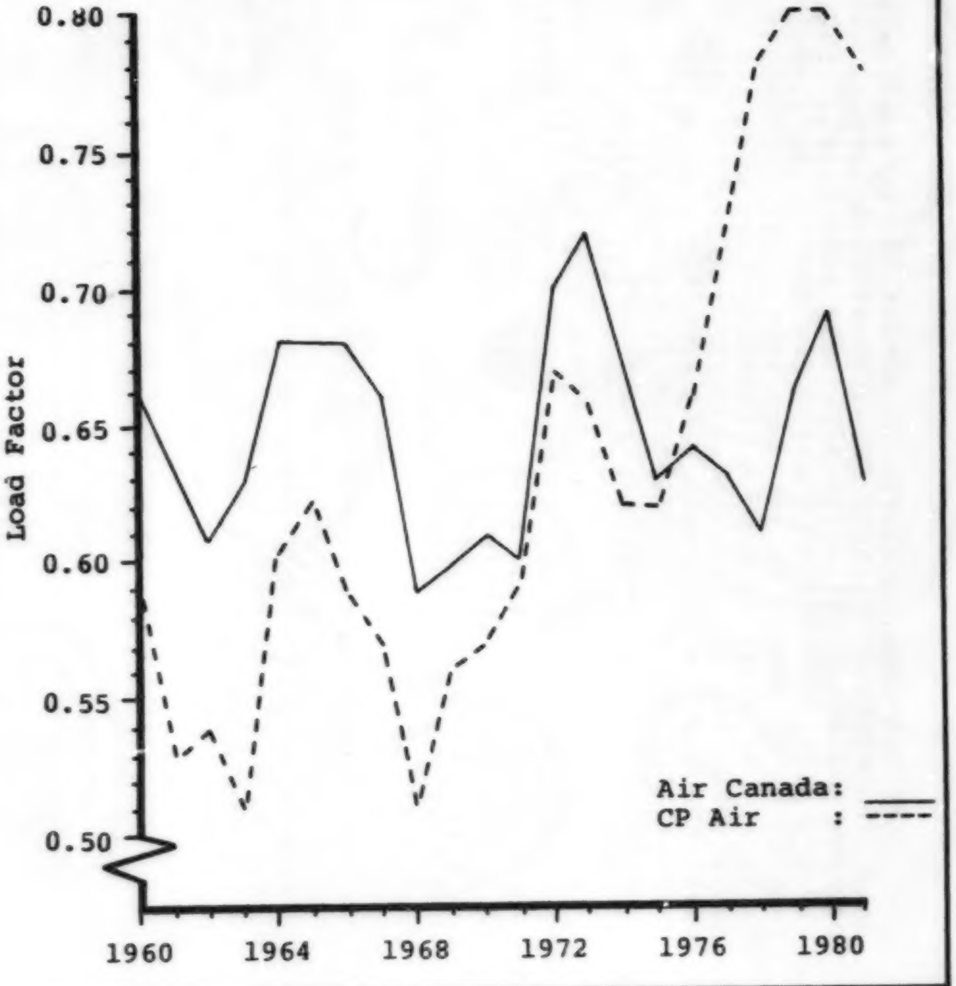

Table D.2

AVERAGE REVENUES,* CONSTANT 1971 DOLLARS
Scheduled Passenger Services

Year	Air Canada	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	0.0841	0.0783	0.1125	0.1220	0.1292	0.1224	0.1290
1961	0.0775	0.0747	0.1095	0.1221	0.1203	0.1178	0.1201
1962	0.0796	0.0745	0.1101	0.1172	0.1109	0.1164	0.1206
1963	0.0804	0.0737	0.1124	0.1150	0.1266	0.1126	0.1607
1964	0.0771	0.0718	0.1144	0.1134	0.1170	0.1139	0.1086
1965	0.0737	0.0698	0.1132	0.1070	0.1126	0.1142	0.1113
1966	0.0697	0.0671	0.1048	0.0996	0.1055	0.1114	0.1146
1967	0.0654	0.0623	0.1060	0.0976	0.1045	0.1039	0.1176
1968	0.0647	0.0596	0.1005	0.0931	0.1033	0.1037	0.1102
1969	0.0616	0.0571	0.0931	0.0926	0.0841	0.0962	0.0944
1970	0.0597	0.0525	0.0960	0.0851	0.0790	0.0942	0.0847
1971	0.0639	0.0533	0.0994	0.0857	0.0856	0.0958	0.0834
1972	0.0574	0.0489	0.0945	0.0833	0.0882	0.0923	0.0793
1973	0.0526	0.0466	0.0893	0.0771	0.0809	0.0855	0.0732
1974	0.0522	0.0481	0.0919	0.0834	0.0839	0.0952	0.0754
1975	0.0562	0.0473	0.0918	0.0838	0.0802	0.0913	0.0739
1976	0.0550	0.0453	0.0911	0.0753	0.0802	0.0929	0.0758
1977	0.0550	0.0454	0.0892	0.0770	0.0809	0.0935	0.0769
1978	0.0525	0.0442	0.0914	0.0713	0.0793	0.0907	0.0741
1979	0.0490	0.0420	0.0881	0.0762	0.0674	0.0877	0.0720
1980	0.0518	0.0426	0.0896	-	0.0679	0.0947	0.0729
1981	0.0550	0.0444	0.0922	-	0.0772	0.0979	0.0733

* Total Revenues/Revenue Passenger-Miles deflated by CPI.

Source: Aviation Statistics Centre.

Table D.3

AVERAGE REVENUES, CONSTANT DOLLARS
Charter Passenger and Goods Services

Year	Air Canada	CP	PWA	Transair	Nordair	Quebecair	EPA
1970	0.2923	0.2927	0.3491	0.4951	0.5694	0.5042	2.1873
1971	0.2790	0.2743	0.3520	0.4579	0.4571	0.3817	1.3650
1972	0.2622	0.2948	0.3686	0.4288	0.4142	0.3478	1.5342
1973	0.2529	0.2779	0.2978	0.3637	0.4129	0.3017	1.1479
1974	0.2787	0.3317	0.2811	0.3092	0.3813	0.2876	0.3457
1975	0.2778	0.2856	0.3014	0.3899	0.3524	0.2704	0.3284
1976	0.2559	0.2281	0.2909	0.2803	0.2961	0.2903	0.2616
1977	0.2476	0.2174	0.2763	0.2779	0.2745	0.3291	0.3046
1978	0.2672	0.2479	0.2836	0.2564	0.2745	0.3454	0.2949
1979	0.2553	0.2692	0.2674	0.2674	0.2671	0.3977	0.2767
1980	0.3114	0.3399	0.2658	-	0.3323	0.6883	0.3332
1981	0.3230	0.3038	0.3163	-	0.3208	0.4998	0.3886

Source: Aviation Statistics Centre.

Table D.4

AVERAGE REVENUES, CONSTANT DOLLARS
Unit-Toll Passenger and Goods Services

Year	Air Canada	CP	PWA	Transair	Nordair	Quebecair	EPA
1960	0.8335	0.7863	1.0847	1.3034	0.9305	1.2688	0.9400
1961	0.7672	0.7517	1.0516	1.3169	0.9242	1.2164	0.9038
1962	0.7766	0.7427	1.4023	1.2510	0.8696	1.2225	0.9709
1963	0.7732	0.7313	1.0163	1.2346	0.9018	1.1721	1.1985
1964	0.7341	0.7037	1.0465	1.2368	0.8363	1.1825	1.0136
1965	0.6933	0.6811	1.0114	1.1707	0.8473	1.1861	0.9697
1966	0.6501	0.6464	0.9605	1.0950	0.7486	1.1534	0.9630
1967	0.6128	0.6026	0.9585	1.0553	0.8218	1.0835	0.9970
1968	0.5868	0.5615	0.9307	0.9703	0.7686	1.0921	0.9519
1969	0.5487	0.5358	0.8872	0.9194	0.6465	1.0129	0.8673
1970	0.5297	0.4980	0.9085	0.8668	1.1151	0.9903	0.8001
1971	0.5435	0.4941	0.9443	0.8858	0.5066	0.9904	0.8065
1972	0.4986	0.4586	0.8589	0.8372	0.5510	0.9591	0.7762
1973	0.4637	0.4381	0.8573	0.7666	0.6308	0.8915	0.7224
1974	0.4678	0.4434	0.8230	0.8407	0.6963	0.9641	0.7531
1975	0.4996	0.4295	0.8126	0.8419	0.6716	0.9367	0.7390
1976	0.4854	0.4050	0.8134	0.7580	0.6708	0.9348	0.7599
1977	0.4874	0.4128	0.8043	0.7784	0.6546	0.9309	0.7674
1978	0.4648	0.4031	0.8389	0.7203	0.6477	0.8891	0.7355
1979	0.4406	0.3891	0.8213	0.7554	0.6075	0.8739	0.7174
1980	0.4680	0.3908	0.8495	-	0.6233	0.9359	0.7373
1981	0.4868	0.4015	0.8854	-	0.6869	0.9739	0.7430

Source: Aviation Statistics Centre.

from charter services. Passengers and goods are included in the calculation of ton-miles. As no revenue ton-miles data were available on a carrier-specific basis for charter flights prior to 1970, the data on average revenues commence with 1970.

With respect to unit-toll services, a downward trend is observed for all carriers since 1970. Starting in 1980, however, average revenues began to recover. The carrier recording the greatest drop in average revenue over the 1970-1979 period was Nordair, which went from $1.11 to $0.61 just before 1980-1981 recovery. Fare hikes are at the source of this recovery. The same trend is observed for charter flights, i.e., a substantial decline from 1970 to 1979, followed by an increase from 1979 to 1981. Only Air Canada, CP Air and Quebecair saw their average revenues in constant dollars attain a higher level in 1980-1981 than in the early part of the period under study. For the other regional airlines, in spite of recent increases in average revenues, such revenues remained below their 1970 level in real terms, PWA being the carrier having 1981 average revenue closest to the 1970 level. In sum, in real terms the users of air services benefited from advantageous fares and rates. All of this suggests that the airlines managed to translate any productivity advancement into lower fares.

Revenue, even when measured in real terms, should not be confused with profits. In an inflationary period, cost may well rise faster than revenue, in which case profits should drop. When real revenue falls off, profits generally feel the impact, even if costs are cut. Inflation affecting production costs also affects consumers, particularly when it is passed on wholly or in part in the way of fares. If at such times rising costs are not translated into higher fares, the offer of reduced fares risks dipping prices below the marginal cost and jeopardizing the carrier's financial situation.

To paint a fuller picture of the evolution of Canadian airline output during the 1960-1981 period, a physical measure of output should be considered. Simply examining the impact of the various services on total revenue does not give a complete picture of air traffic development.

The revenue passenger-miles data for the seven air carriers are given in Tables D.5 to D.7. Air Canada shows an upward trend in output from 1960 to 1980 but records a drop in 1981, the year in which some slowdown in economic activity was observed. CP Air followed the same upward trend and seemed unaffected in 1981 by the economic situation. One should nevertheless bear in mind that in spite of a higher load factor, CP Air saw its real average revenue drop during that year.

Table D.5

OUTPUT DATA
Air Canada and CP Air
(,000)

Year	Air Canada ASM	Air Canada ATM	Air Canada RPM	Air Canada RTM	CP Air ASM	CP Air ATM	CP Air RPM	CP Air RTM
1960	3 116 913	400 817	2 050 294	238 199	892 035	110 525	529 297	60 239
1961	3 848 917	519 074	2 481 124	284 657	1 117 608	144 047	587 887	66 485
1962	4 379 270	588 801	2 659 579	309 757	1 385 736	180 073	743 411	82 851
1963	4 586 677	627 373	2 892 241	340 206	1 670 708	219 404	852 417	96 790
1964	4 642 758	670 565	3 143 469	377 090	1 636 512	212 708	984 514	113 944
1965	5 458 505	835 291	3 713 267	452 332	1 837 005	267 514	1 144 941	133 779
1966	6 387 747	983 207	4 328 720	533 000	2 160 269	286 681	1 279 978	153 995
1967	8 054 612	1 202 354	5 339 583	647 853	2 620 899	382 046	1 492 093	181 241
1968	9 716 545	1 471 891	5 723 185	726 960	3 270 828	471 535	1 651 908	207 637
1969	10 057 172	1 601 345	6 019 048	788 606	3 952 060	548 629	2 211 362	271 830
1970	11 652 309	1 943 084	7 157 433	944 535	4 520 835	623 582	2 601 195	312 878
1971	11 942 210	2 027 503	7 152 797	974 540	4 457 416	605 764	2 644 704	325 663
1972	12 415 252	2 101 011	8 701 382	1 160 335	4 378 624	602 020	2 916 827	356 053
1973	14 702 671	2 482 519	10 548 394	1 373 416	4 662 572	657 602	3 090 547	375 557
1974	16 477 370	2 753 336	10 992 237	1 407 799	6 438 534	925 560	4 000 098	493 346
1975	17 791 807	2 938 854	11 297 311	1 440 933	7 243 944	1 019 354	4 467 453	556 230
1976	18 049 321	3 068 957	11 478 149	1 483 592	6 979 934	985 777	4 629 074	584 103
1977	18 220 698	3 026 481	11 509 374	1 469 998	6 848 484	961 014	4 941 346	601 320
1978	19 904 085	3 226 405	12 238 657	1 568 708	6 960 986	970 230	5 403 369	658 601
1979	22 034 145	3 617 320	14 476 782	1 825 266	7 450 118	1 040 089	5 986 545	717 634
1980	22 184 800	3 587 113	15 328 640	1 909 405	8 369 414	1 168 200	6 698 405	807 329
1981	22 717 173	3 642 611	14 350 895	1 816 883	8 840 056	1 242 608	6 900 976	762 982

ASM:	Available Seat-Miles
ATM:	Available Ton-Miles
RPM:	Revenue Passenger-Miles
RTM:	Revenue Ton-Miles

Source: Aviation Statistics Centre.

Table D.6

OUTPUT DATA
PWA, Transair and Nordair
(,000)

Year	PWA		Transair		Nordair	
	RPM	RTM	RPM	RTM	RPM	RTM
1960	32 795	5 402	16 191	2 063	7 903	2 399
1961	31 984	5 132	18 243	2 225	11 819	2 831
1962	32 828	5 261	21 117	2 611	14 136	3 262
1963	34 073	5 603	22 813	2 764	8 990	2 574
1964	89 693	12 241	34 241	8 378	26 285	6 725
1965	113 134	16 108	36 786	8 359	51 100	10 042
1966	130 798	18 279	57 128	8 966	56 229	11 983
1967	161 008	22 247	46 528	7 995	43 377	9 526
1968	225 511	32 840	57 862	9 163	74 729	12 236
1969	395 484	59 483	72 186	12 058	99 197	17 856
1970	532 162	77 623	113 241	15 821	117 982	21 469
1971	461 136	74 758	138 077	18 150	195 854	34 024
1972	492 653	82 358	153 074	19 553	264 635	41 554
1973	618 422	110 805	221 907	28 227	285 847	41 607
1974	670 069	127 391	339 636	39 132	371 944	48 759
1975	692 158	133 455	273 390	31 318	438 350	56 257
1976	801 458	118 956	403 490	45 201	604 511	73 698
1977	1 069 496	146 356	364 696	40 907	699 310	85 278
1978	1 097 460	140 803	418 067	47 071	700 126	85 101
1979	1 050 467	139 865	302 732	34 198	1 050 959	120 767
1980	1 368 824	171 299	-	-	850 106	101 646
1981	1 533 620	138 105	-	-	810 641	56 592

RPM: Revenue Passenger-Miles
RTM: Revenue Ton-Miles

Source: Aviation Statistics Centre.

Table D.7

OUTPUT DATA
Quebecair and EPA
(,000)

Year	Quebecair RPM	Quebecair RTM	EPA RPM	EPA RTM
1960	31 082	3 691	12 678	4 494
1961	29 204	3 467	17 892	5 254
1962	33 828	3 923	22 366	5 044
1963	34 145	3 960	17 665	4 007
1964	33 859	3 900	30 246	5 238
1965	35 905	4 171	24 834	4 864
1966	45 463	5 299	28 615	5 641
1967	50 876	5 808	30 667	5 854
1968	55 623	6 970	36 693	6 443
1969	77 277	10 580	60 511	9 111
1970	89 279	10 264	111 786	14 562
1971	128 650	14 292	149 568	18 433
1972	151 055	16 779	169 975	20 668
1973	191 407	21 572	226 336	26 428
1974	247 958	29 774	296 773	33 603
1975	583 025	65 386	329 635	36 903
1976	530 050	59 635	333 951	37 399
1977	708 881	80 690	341 149	37 994
1978	783 101	87 443	381 379	42 985
1979	613 621	68 064	405 483	45 662
1980	370 291	39 308	397 344	44 316
1981	498 764	17 383	441 156	46 913

RPM: Revenue Passenger-Miles
RTM: Revenue Ton-Miles

Source: Aviation Statistics Centre.

PWA more than doubled its operations in terms of passenger-miles between 1963 and 1964, leaping from 34 073 to 89 693 RPM. During the period under review, PWA recorded a slight drop in 1971, followed by another in 1979. Its traffic has continued to rise since then.

Transair, too, recorded an upward trend in operations since 1960. Expansion of freight services is observed between 1963 and 1964. However, from 1975 until the airline merged with PWA, its traffic in terms of passenger-miles proved unstable. Table D.6 shows three increases and three drops over the six years prior to merger.

Following a general upward trend in revenue passenger-miles for Nordair, Quebecair and PWA, the trough of the wave came in 1980. Except for Nordair, the RPM data already indicate some recovery in 1981 in spite of unfavourable economic conditions in the air transport industry. At Quebecair charter services accounted for the traffic growth observed in 1981 over the previous year.

Appendix E

PRODUCTIVITY COMPARISONS

In an earlier CTC study (1978), productivity performance of major Canadian air carriers was measured using Tornqvist approximation to the Divisia index. In the text, comparisons of the carriers' productivity were made and the reader was asked to use considerable caution to avoid incorrect inferences from such comparisons. In its very essence, economics is concerned with the utilization of inputs (scarce resources) to produce outputs which will satisfy human needs.

A productivity measure allows one to assess the performance of a firm in using inputs to produce outputs. The use of productivity measures as measures of performance designed to highlight possible problems and to stimulate action if needed, is possible but it requires standards of comparisons. It is difficult to measure productivity attained by various carriers without stimulating an interest for comparisons between carriers' performance, especially when differences in productivity are observed. Comparisons of productivity designed to stimulate action have to involve both levels and rates of change. But before action is taken, an important question to ask is whether comparisons of firms' productivity levels are acceptable. Therefore comparison of productivity levels is at the heart of the assessment of economic performance. At the analytical level, productivity comparisons aim at measuring the relative efficiency with which resources are used to obtain output. Such comparisons constitute complex exercises since there can be an almost endless chain of measures designed to ensure that precisely the same outputs are related to precisely the same inputs. If one was able to standardize all the outputs and take account of all the inputs, some believe that the remaining differences in productivity would truly reflect efficiency differences.

The Tornqvist approximation to the Divisia index uses value shares that are specific to the two entities being compared, a property referred in the index number literature as 'characteristicity'. Therefore, Divisia indexes permit bilateral (binary) comparisons which do not necessarily result in transitive multilateral comparison. Characteristicity and transitivity have been found to be two properties of index numbers which are in conflict with each other. Therefore, to obtain a transitive index, one has to sacrifice some degree of characteristicity. Caves, Christensen and Diewert (1982) have demonstrated that 'superlative'* index numbers, that maintain transitivity and a high degree of characteristicity, can be used for making multilateral comparisons. They have defined the output (input) of a firm relative to the output (input) comparisons between the said firm and each of the firms. From such a definition, transitive results are obtained in the multilateral setting and the productivity comparisons are obtained from the comparisons of outputs relative to inputs. With panel data (combination of cross-section and time-series data), the multilateral approach treats all firms and time periods symmetrically. In the case of the Canadian air transport industry, such a symmetry in the treatment of air carriers was found to be debatable, as shown in the text.

Here the growth and relative levels of productivity for the seven major Canadian carriers for the period 1960 to 1981 were estimated. The following index of total factor productivity is used in this study.

$$\begin{aligned}\ln TFP_k - \ln TFP_l = & \sum_j \frac{r_{jk} + r_{jl}}{2} \ln \frac{Q_{jk}}{Q_{jl}} \\ & - \sum_i \frac{s_{ik} + s_{il}}{2} \ln \frac{X_{ik}}{X_{il}}\end{aligned} \tag{1}$$

where k and l are adjacent time periods. This procedure allows the measurement of the performance of a given carrier. For making productivity comparisons among a combined time series and cross section of air carriers, the subscripts k and l in (1) represent firms and time period — 7 carriers and 22 time periods — for a total of 152 time-differentiated carrier observations (Transair being part of PWA's operations as of 1980). Therefore, if (1) is used to compare air carrier productivity, a total of 11 476 binary comparisons is possible, e.g., the number of possible ways of selecting 2 of the 152 observations to compare. Because the weights (r_{jk} and s_{ik}) are carrier specific, the comparisons made with (1) might lack transitivity. Traditionally, the solution to this problem has been to use weights which are not specific to the individual observation. However, the comparison is then no longer based on economic conditions specific to the two carriers being compared (which implies in the index number jargon a lack of characteristicity).

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* A superlative index number formula is one which is consistent with a flexible functional form of the underlying production function.

Transitivity and characteristicity are two index number properties impossible to achieve simultaneously. Caves, Christensen and Diewert (1982) have proposed to define the productivity of firm k relative to the productivity of all firms as the geometric mean of the bilateral productivity comparisons between k and each of the firms:

$$\begin{aligned} \ln \mathrm{TFP} = {} & \frac{1}{2} \sum_j (r_j^k + \bar{r}_j)(\ln Q_j^k - \overline{\ln Q_j}) + \bar{r}_j \, \overline{\ln Q_j} - \overline{r_j \ln Q_j} \\ & - \frac{1}{2} \sum_i (s_i^k + \bar{s}_i)(\ln X_i^k - \ln \bar{X}_i) + \bar{s}_i \, \overline{\ln X_i} - \overline{s_i \ln X_i} \end{aligned} \tag{2}$$

where the bar indicates the arithmetic mean over the firms of the variable or product under the bar. From there on, this index will be referred to as the translog multilateral productivity index and it was estimated for the Canadian air carriers over the period 1960-1981. For binary comparisons, the formula (1) becomes:

$$\begin{aligned} \overline{\ln \mathrm{TFP}_k} - \overline{\ln \mathrm{TFP}_l} = {} & \sum_j \frac{r_{jk} + \bar{r}_j}{2} \ln \frac{Q_{jk}}{\tilde{Q}_j} - \sum_j \frac{r_{jl} + \bar{r}_j}{2} \ln \frac{Q_{jl}}{\tilde{Q}_j} \\ & - \sum_i \frac{s_{ik} + \bar{s}_i}{2} \ln \frac{X_{ik}}{\tilde{X}_i} + \sum_i \frac{s_{il} + \bar{s}_i}{2} \ln \frac{X_{il}}{\tilde{X}_i} \end{aligned} \tag{3}$$

where a bar over a variable indicates the arithmetic mean and a tilde over a variable indicates the geometric mean. Transitive multilateral comparisons retaining a high degree of characteristicity are obtained with (3). Equation (3) was used to compute TFP indexes for the 7 Canadian air carriers. The results are presented in Chapter 4.

Appendix F

CALCULATION OF GROWTH RATE OF WEIGHTED TFP

In order to explain the sources of productivity variation, a covariance analysis was carried. The results of the decomposition of productivity variations were found to be not only unstable from one year to another but also sensitive to the number of carriers from which the comparison is derived. This appendix explains why the results are so responsive to the actual number of carriers included in the industry's definition.

Let us bear in mind that Tables 4.8 to 4.11 were obtained by multiplying each carrier's share of the total expenditure in total industry expenditures by their covariance analysis coefficient. In other words,

$$\beta_{TFP} * TFP_{t,k} * [\text{expenditure}_{t,k} / \sum_k \text{expenditure}_{t,k}]$$

$$\beta_{OUT} * OUT_{t,k} * [\text{expenditure}_{t,k} / \sum_k \text{expenditure}_{t,k}] \qquad (1)$$

$$\beta_{ATH} * ATH_{t,k} * [\text{expenditure}_{t,k} / \sum_k \text{expenditure}_{t,k}]$$

where β is the coefficient of the covariance analysis, t is the time period (year) and k is the carrier.

Let us note also that the only difference between the definition of the five-carrier and four-carrier industries is the inclusion of PWA in the former. Still, the addition of a single carrier is apparently sufficient to produce different results. As the coefficients used (β) to obtain Tables 4.8 to 4.11 are not significantly different (see Tables 4.5 to 4.7), the weighted average of each of the variables is at the source of the dissimilarities in the results. If all of the carriers are similar, each one's average share relative to the industry ($exp_{t,k}/\sum_k exp_{t,k}$) shows little variation when a carrier is added. But if the carriers are different, the average share of each one will be more sensitive to the number of carriers in the industry group. The method used is thus a function of the individual, specific characteristics of each airline. Given a heterogeneous industry, equation system (1) produces very different results depending on the number of firms, even for similar β's.

This can be simply illustrated by using an example. Taking an extreme case, if all of the carriers had the same weight in the industry:

for $\text{expenditure}_k = 10 \qquad k = 1,\ldots,10 \qquad \sum_k \text{expenditure}_k = 100$

and $\dfrac{exp_k}{\sum_k exp_k} = \dfrac{10}{100} = 0.10$ for each k, thus for each carrier

by reducing to $k = 1,\ldots,9, \ \sum_k exp_k = 90$

and $\frac{exp_k}{\sum_k exp_k} = \frac{10}{90} = 0.11$ for each carrier

If all of the carriers are different:

$exp_1 = 10 \quad exp_2 = 5 \quad exp_3 = 3 \quad exp_4 = 2 \quad exp_5 = 4$

$$\sum_{k=1}^{5} exp_k = 24$$

$$\frac{exp_1}{\sum_{k=1}^{5} exp_k} = \frac{10}{24} = 0.42$$

By removing the first carrier:

$$\sum_{k=2}^{5} exp_k = 14 \; ; \; \frac{exp_2}{\sum_{k=2}^{5} exp_k} = \frac{5}{14} = 0.36$$

the weight of the second carrier rises from 0.21 to 0.36.

Analyses of covariance based on the translog multilateral indices of productivity and output take account of the characteristicity of each carrier. This explains why the results of the decomposition of productivity into its explanatory variables differ so greatly depending on the composition of the industry and are even more dissimilar if the firms within the industry are heterogeneous.